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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5)

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## TITLE OF INVENTION

**CURVE GENERATING APPARATUS AND CURVE GENERATING METHOD, AND PROGRAM RECORDING MEDIUM**

APPLICANT(S) FOR DO/EO/US

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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

- This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
- This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
- This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
- A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
- A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - is transmitted herewith (required only if not transmitted by the International Bureau).
  - has been transmitted by the International Bureau.
  - is not required, as the application was filed in the United States Receiving Office (RO/US).
- A translation of the International Application into English (35 U.S.C 371(c)(2)). **w/Verification of Translation**
- A copy of the International Search Report (PCT/ISA/210).
- Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - are transmitted herewith (required only if not transmitted by the International Bureau).
  - have been transmitted by the International Bureau.
  - have not been made; however, the time limit for making such amendments has NOT expired.
  - have not been made and will not be made.
- A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
- An oath or declaration of the inventor(s) (35 U.S.C 371 (c)(4)). **(unsigned)**
- A copy of the International Preliminary Examination Report (PCT/IEPA/409).
- A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

## Items 13 to 20 below concern document(s) or information included:

- An Information Disclosure Statement under 37 CFR 1.97 and 1.98. **w/Form 1449 and cited prior art refs.**
- An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
- A **FIRST** preliminary amendment.
- A **SECOND** or **SUBSEQUENT** preliminary amendment.
- A substitute specification.
- A change of power of attorney and/or address letter.
- Certificate of Mailing by Express Mail
- Other items or information:
  - a.) Forms PCT/IB/301, 304 and 308;
  - b.) Front page of published application No. WO00/51079 as published on August 31, 2000;
  - c.) Certified translation of Japanese priority patent application No. P11-051867 filed on February 26, 1999;
  - d.) PCT Easy Request;

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5) <b>09/673202</b>	INTERNATIONAL APPLICATION NO. PCT/JP00/01123	ATTORNEY'S DOCKET NUMBER <b>KOIK-T0215</b>						
21. The following fees are submitted:		<b>CALCULATIONS PTO USE ONLY</b>						
<b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):</b>								
<input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$970.00</b> <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$840.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$690.00</b> <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$670.00</b> <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$96.00</b>								
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Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). <b>\$0.00</b>								
CLAIMS	NUMBER FILED	NUMBER EXTRA						
Total claims	11 - 20 =	0						
Independent claims	3 - 3 =	0						
Multiple Dependent Claims (check if applicable).		<input type="checkbox"/>						
<b>TOTAL OF ABOVE CALCULATIONS =</b>		<b>\$860.00</b>						
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) (check if applicable). <input type="checkbox"/> <b>\$0.00</b>								
<b>SUBTOTAL =</b>		<b>\$860.00</b>						
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). <b>+ \$0.00</b>								
<b>TOTAL NATIONAL FEE =</b>		<b>\$860.00</b>						
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). <input type="checkbox"/> <b>\$0.00</b>								
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<input checked="" type="checkbox"/> A check in the amount of <b>\$860.00</b> to cover the above fees is enclosed.  <input type="checkbox"/> Please charge my Deposit Account No. <b>12-1420</b> in the amount of <b> </b> to cover the above fees. A duplicate copy of this sheet is enclosed.  <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. <b>12-1420</b> A duplicate copy of this sheet is enclosed.								
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>								
SEND ALL CORRESPONDENCE TO: <div style="border: 1px solid black; padding: 10px;"> Charles P. Sammut, Esq.  Limbach &amp; Limbach L.L.P.  2001 Ferry Building  San Francisco, CA 94111  (415) 433-4150 </div> <div style="text-align: right; margin-top: 20px;">   <b>SIGNATURE</b>  Mayumi Maeda  NAME  40,075  REGISTRATION NUMBER  October 12, 2000  DATE </div>								

## [Title of the Invention]

Curve Generating Apparatus and Curve Generating Method, and Program Providing Medium

## [Claims]

## [Claim 1]

A curve generating apparatus adapted for generating, from curve to be generated or processed of first frame, curve at second frame,

the apparatus comprising:

correspondence point detecting means for determining, by using the curve to be generated of the first frame, correspondence point at the second frame corresponding to reference correspondence point set on the curve to be generated of the first frame; and

curve generating means for generating curve of the second frame passing through the correspondence point detected by the correspondence point detecting means.

## [Claim 2 ]

The curve generating apparatus as set forth in claim 1, wherein the correspondence point detecting means carries out picture image pursuit of reference correspondence point set on the curve to be generated of the first frame to determine correspondence point at the second frame.

[Claim 3]

The curve generating apparatus as set forth in claim 1, wherein the curve generating means is adapted so that when the first frame is caused to be frame at the time of start and frame at the time of end is caused to be third frame, it determines interpolated curve by linear interpolation from curve to be generated of the first frame and curve of the third frame to deform this interpolated curve into curve passing through the correspondence point detected by the correspondence point detecting means.

[Claim 4]

The curve generating apparatus as set forth in claim 1, wherein the curve generating means generates, as curve, shape along edge

of picture image passing through correspondence point detected by the correspondence point detecting means.

[Claim 5]

The curve generating apparatus as set forth in claim 1, wherein the curve generating means generates contour curve of object on picture image.

[Claim 6]

A curve generating method for generating, from curve to be generated or processed of first frame, curve at second frame,

the method comprising:

a correspondence point detection step of determining, by using curve to be

generated of the first frame, correspondence point at the second frame corresponding to reference correspondence point set on the curve to be generated of the first frame; and

a curve generating step of generating curve of the second frame passing through the correspondence point detected by the correspondence point detection step.

[Claim 7]

The curve generating method as set forth in claim 6, wherein, at the correspondence point detection step, a procedure is taken to carry out picture image pursuit of reference correspondence point set on the curve to be generated of the first frame to determine correspondence point at the second frame.

[Claim 8]

The curve generating method as set forth in claim 6, wherein, at the curve generating step, a procedure is taken such that when the first frame is assumed to be frame at the time of start and frame at the time of end is assumed to be third frame, interpolated curve is determined by linear interpolation from the curve to be generated of the first frame and curve of the third frame to deform this interpolated curve into curve passing through the correspondence point detected at the correspondence detection step.

[Claim 9]

The curve generating method as set forth in claim 6, wherein, at the curve generating step, a procedure is taken to generate, as curve, shape along edge of picture

image passing through correspondence point detected at the correspondence point detection step.

[Claim 10]

The curve generating method as set forth in claim 6, wherein, at the curve generating step, a procedure is taken to generate contour curve of object on picture image.

[Claim 11]

A program providing medium adapted so that there is provided program relating to curve generating processing for generating curve at second frame from curve to be generated or processed of first frame,

the program comprising:

a correspondence point detection step of determining, by using curve to be generated of the first frame, correspondence point at the second frame corresponding to reference correspondence point set on the curve to be generated of the first frame; and

a curve generation step of generating curve of the second frame passing through the correspondence point detected by the correspondence detection step.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

This invention relates to a curve generating apparatus and a curve generating

method used in CAD, graphics, picture editing, etc. which edit curve indicating contour shape of object included within picture image on the computer, and a program providing medium adapted so that program relating to the curve generating method is provided.

[0002]

[Prior Art]

Hitherto, there are many instances where contour extraction processing for extracting contour shape of object included in plural picture image data constituting moving picture image are used in the field of picture image processing, e.g., CAD, graphics technologies, etc. Among these picture image processing, when picture image synthesis processing is carried out, there is the processing which generates key signals from contour shape of the object, and it is important to generate precise or accurate key signals, i.e., precise contour shape. In this case, the key signal is information for cutting off the area of the foreground object to be synthesized and is also called mask.

[0003]

The contour extraction processing is required to have interactive operability as in the case where operator gives in detail information such as contour position or direction, etc. with respect to object. As such contour extraction processing, there are processing to designate plural points on the contour of object to prepare shapes between respective points, processing to operate control points of parametric curve

indicating counter shape, and processing to directly input contour shape by mouse, etc. As examples of these contour extraction processing, there are known "Intelligent Scissors for Image Composition" (Eric N. Mortensen and William A. Barrett, Computer Graphics Proceedings, Annual Conference Series, 1995, ACM SIGGRAPH, pp. 191-198), "Image contour detection method" (Japanese Patent Application Laid Open No. 152481/1992 publication), and "Cutting mask preparation method and cutting mask preparation apparatus" (Japanese Patent Application Laid Open No. 254854/1992 publication).

[0004]

Moreover, in the contour extraction processing, it is required to get precise contour shape with respect to all picture images constituting moving picture. For example, in cinemas or television picture images, several hundreds of key signals are required for generating images of several seconds, and the quantity of processing is vast. For this reason, the contour extraction processing used in the field of cinema, etc. is desired (required) that more precise contour shape can be prepared by lesser number of operations. This results from the fact that, in the conventional contour extraction processing, processing for preparing contour shapes with respect to respective frames constituting moving picture is the processing which requires extremely much time and labor.

[0005]

In view of the above, as a method of preparing contour shape by more simple

procedure, there was proposed a method in which, on the premise that, in moving picture images having continuous property, contour shape at the start frame changes with passage of time so that it changes to contour shape at the end frame, intermediate shape of contour at the intermediate frame is prepared by interpolation processing from contour shape at the start frame and contour shape at the end frame.

[0006]

In accordance with such an interpolation processing, as shown in FIG. 35, plural points constituting contour shape are caused to have one-to-one correspondence relationship at contour shape of the start frame and contour shape of the end frame. Namely, when it is assumed that curve indicating contour shape at the start frame is curve 0, curve indicating contour shape at the end frame is curve 1, the time at the start frame is 0, the time at the end frame is 1, and curve changes in point of time, it can be considered that curve 0 at time 0 changes to curve 1 at time 1. In view of the above, when time at which interpolation of two curves is carried out is assumed to be T, and coordinate at the point on the curve 0 is put by A and coordinate at the point on the curve 1 corresponding to the coordinate A is put by B, coordinate C at required intermediate form can be represented as follows.

$$C = T \cdot A + (1-T) \cdot B$$

In the conventional interpolation processing, contour at the intermediate frame was prepared from train of points determined by such interpolating calculation.

[0007]

Further, it is assumed that contour shapes with respect to respective frames are constituted by plural third-order Bezier curve. The third-order Bezier curve is defined by

$$Q(t) = ((1-t)^3)M + 3t((1-t)^2)N + 3(t^2)(1-t)O + (t^3)P \quad (0 \leq t \leq 1)$$

as indicated by the article “Computer Graphics PRINCIPLE AND PRACTICE SECOND EDITION in C” (Foley, van Dam, Feiner, Hughes, ADDISON WESLEY, 1996, ISBN 0-201-84840-6). In this formula, M, N, O, P are coordinates indicating points on the two-dimensional plane wherein M and P are end points of line segment, and N, O are control points. An example of line segment of the third order Bezier curve represented by the above-mentioned formula is shown in FIG. 36. In FIG. 36, curve indicated by solid line is the third-order Bezier curve, wherein M, P indicated by points of black circle are end points, and points N, O indicated by white circle are control points.

[0008]

In accordance with the formula which defines the above-described Bezier curve, locus of the third-order Bezier curve, i.e., shape is represented by coordinates of end points and control points indicated by points M, N, O, P and change of time t in FIG. 36.

[0009]

When constituting unit of the third-order Bezier curve shown in FIG. 36 is assumed to be segment, it can be said that single curve indicating contour shape is

ordinarily composed of plural segments as shown in FIG. 37. In this case, end points of adjacent segments are shared so that one curve is constituted as the entirety.

[0010]

[Problems to be Solved by the Invention]

In the above-described conventional contour extraction processing, in the case where intermediate shape is determined from contour shapes of frames before and after in point of time, interpolation was carried out in the state where control points and end points constituting segments are caused to have one-to-one correspondence relationship.

[0011]

However, at frames before and after in point of time, there are instances where contour shape does not linearly move.

[0012]

In the above-mentioned method, in the case where contour shape move non-linearly, shape different from contour shape was prepared.

[0013]

In order to avoid such problems, it is conceivable to carry out work to divide interval of shape in point of time between the time of start and the time of end into narrower ranges to carry out processing for a second time, or to manually modify the shape, etc. For this reason, there took place the problem that labor of user was required in preparing shape, and there took place fine unevenness of shape because

shape discontinuously changing was prepared in the time axis direction owing to manual modification.

[0014]

This invention has been made in view of actual circumstances as described above, and its object is to provide a curve generating apparatus and a curve generating method in which, in the processing for preparing intermediate shape of two curves, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour, thus to prepare contour shapes with higher precision.

[0015]

[Means to Solve the Problem]

For this reason, to solve the problem described above, the curve generating apparatus according to this invention is directed to a curve generating apparatus adapted for generating, from curve to be generated of first frame, curve at second frame, the apparatus comprising: correspondence point detecting means for determining, by using curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and curve generating means for generating curve of the second frame passing through correspondence points detected by the correspondence point detecting means.

[0016]

Moreover, to solve the problem described above, the curve generating method according to this invention is directed to a curve generating method for generating, from curve to be generated of the first frame, curve at second frame, the method comprising: a correspondence point detection step of determining, by using the curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and a curve generation step of generating curve of the second frame passing through the correspondence points detected by the correspondence detection step.

[0017]

In addition, to solve the problem described above, the program providing medium according to this invention is directed to a program providing medium for providing program relating to curve generation processing for generating, from curve to be generated of first frame, curve at second frame, wherein there is provided program comprising: a correspondence point detecting step of determining, by using the curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and a curve generation step of generating curve of the second frame passing through the correspondence points detected by the correspondence point detection step.

[0018]

[Preferred Embodiment of the Invention]

Preferred embodiments of this invention will now be described in detail with reference to the attached drawings.

[0019]

A curve generating apparatus 1 to which this invention is applied is caused to be of configuration as shown in FIG. 1, for example. This curve generating apparatus 1 is adapted so that an arithmetic processing unit 2, a program memory 3, a data memory 4, a frame memory 5, an operation input unit 6, and an external storage (memory) unit 7 are connected to a bus 8.

[0020]

In the program memory 3, there is recorded program for executing a curve generating method according to this invention. Namely, the program memory 3 records therein, as software program, the curve generating method comprising a correspondence point detection step of determining, by using curve to be generated or processed of the first frame, correspondence points at second frame corresponding to reference correspondence points set on the curve to be generated of the first frame, and a curve generation step of generating curve of the second frame passing through correspondence points detected by the correspondence point detection step.

[0021]

The curve generating apparatus 1 includes the operation input unit 6 which is comprised of, e.g., keyboard and/or mouse, etc. and serves to generate an operation

input signal as the result of the fact that it is operated by user. This operation input unit 6 outputs the operation input signal to the arithmetic processing unit 2.

[0022]

The arithmetic processing unit 2 generates control signals with respect to the above-described respective units in accordance with operation input signals from the operation input unit 6. Further, the arithmetic processing unit 2 outputs control signals thus generated to respective units to thereby carry out processing corresponding to the operation input signals. Namely, the arithmetic processing unit 2 conducts such a control to read out in sequence the software programs from the program memory 3 to execute them to generate contour curve indicating contours of curves to be generated included in respective frames by using picture data indicating moving picture stored in the external storage (memory) unit 7.

[0023]

Picture image data processed by the software program from the program memory 3 is stored in the external storage (memory) unit 7. The external storage (memory) unit 7 comprises recording medium, e.g., optical disc, etc. and outputs, in accordance with control signal from the arithmetic processing unit 2, picture data indicating moving picture recorded on the recording medium to the arithmetic processing unit 2, the data memory 4 and the frame memory 5. In addition, the external storage (memory) unit 7 records the picture data onto the recording medium.

[0024]

As shown in FIG. 2, for example, picture image data stored in the external storage (memory) unit 7 consists of plural frames and shows moving picture. In this example, the start frame is the Fr1, for example, and the end frame with respect to the frame Fr1 is frame Fr3. Namely, this curve generating apparatus 1 executes the program to thereby generate intermediate curve with respect to frame Fr2 which is intermediate frame by using first contour curve of data to be generated included in the frame Fr1 and second contour curve of data to be generated included in the frame Fr3.

[0025]

In the data memory 4, there is stored contour curve indicating contour of intermediate frame generated by the above-described arithmetic processing unit 2 according to the program. In addition, into this data memory 4, data in the middle of arithmetic processing according to the program is also input.

[0026]

Picture image data corresponding to one frame from the data memory 4 or the external storage (memory) unit 7, etc. is input to the frame memory 5 in accordance with control signal of the arithmetic processing unit 2. Picture image data which has been read out by control signal from, e.g., arithmetic processing unit 2 or contour curve indicating intermediate frame generated by the program, etc. is inputted to the frame memory 5. Further, this frame memory 5 is connected to a display unit 9 for displaying picture image and/or processing content, etc. to user, and outputs picture image data, etc. inputted in accordance with control signal to the display unit 9 to

thereby allow the display unit 9 to display thereon picture image that the above-mentioned picture image data indicates.

[0027]

The program to which the curve generating method of this invention is applied is operated by the processing procedure shown in FIG. 3.

[0028]

At step S101, user gives, as input, two curves at the time of start and at the time of end and reference correspondence points with respect to respective curves. In this case, two curves are respectively referred to as curves A and B. It is required that the numbers of reference correspondence points are the same with respect to the curves A and B. Then, at step S102, pursuit operation of reference correspondence points is carried out with respect to picture images successive in the time axis direction. As a result, positions of reference correspondence points at respective intermediate stages can be determined. The detail thereof will be described later.

[0029]

Then, at step S103, interpolation of shape is carried out. Interpolation calculation of shape is employed to carry out interpolation calculation of coordinates of point trains on two curves to thereby determine coordinates of points of intermediate shapes. Although there may be employed any transformation (conversion) to provide intermediate shape of two shapes, there is employed in this example the technology disclosed in the Japanese Patent Application No. 251492/1998

by the applicant of this application. The detail thereof will be described later.

[0030]

Then, at step S104, the interpolated shape determined at the step S103 is deformed in correspondence with reference correspondence points determined by pursuit operation at the step S102.

[0031]

Accordingly, by executing the program, it can be equivalently said that the arithmetic processing unit 2 comprises a correspondence point detecting section for determining, by using curve to be generated or processed of the first frame, correspondence points at intermediate frame corresponding to reference correspondence point set on the curve to be generated of frame at the time of start, and a curve generating section for generating curve of intermediate frame passing through correspondence point detected by the correspondence point detecting section.

[0032]

Particularly, the above-mentioned correspondence point detecting section carries out picture image pursuit operation at the step S102 to detect where reference correspondence point on curve to be generated or processed of frame at the time of start is positioned at the intermediate frame.

[0033]

In addition, the curve generating section generates curve passing through correspondence points detected by the correspondence point detecting section through

the steps S103 and S104. In more practical sense, when frame at the time of end is assumed to be the third frame, interpolated curve is determined by linear interpolation from curve to be generated or processed of the first frame and curve to be generated or processed of the third frame to deform the interpolated curve thus obtained into curve passing through correspondence points detected at the correspondence point detecting section.

[0034]

Operations at the respective steps of FIG. 3, i.e., processing that the arithmetic processing unit 2 carries out will now be described in detail.

[0035]

At step S102, there is carried out an operation to pursue position of reference correspondence points in picture images successive on the time axis. As a pursuit method of picture image, there may be employed any methods of pursuing points on the picture image. Here, explanation will be given with reference to FIG. 4 in connection with a method of carrying out pursuit by using absolute value sum of differences of picture images, which is known as SSD as an example. When picture image around reference correspondence point 10 at pursuit source frame F0 shown in FIG. 4 (A) is assumed as pursuit source image 20, pursuit destination images 40 are prepared with respect to all coordinates within the region of search range 30 designated at frame F1 which is pursuing at present shown in FIG. 4 (B) to determine by calculation analogousness between two images. As a method of determining

analogousness between images, there is used a method of determining absolute value sums of differences of respective pixel values within image region with respect to two images to allow them to be evaluation value to allow coordinates having the lowest evaluation value within the region to be pursuit result.

[0036]

Explanation will now be described in connection with interpolation calculation of shape at step S103 will be described below. In FIG. 5, there are shown two curves where the numbers of segments are not in correspondence with each other. An example for generating intermediate curve when change from first contour curve A to second contour curve B takes place using first contour curve A and second contour curve B will now be described. In this case, when end point, control point and line segment of third-order Bezier curve are assumed to be one segment, the first contour curve A consists of five segments and the second contour curve B consists of three segments. In addition, when intermediate curve in the case where change from first contour curve A to second contour curve B takes place as shown in FIG. 6, for example, is generated, procedure shown in the flowchart of FIG. 7 is taken.

[0037]

When the intermediate curve is generated, the operation input signal as the result of the fact that user operates keyboard, etc. is input designating correspondence points indicating corresponding positions of the first contour curve A and the second contour curve B.

[0038]

Thus, at step S1, correspondence points are set at the first contour curve A and the second contour curve B in accordance with the operation input signal to the effect that the above-described correspondence points are designated to develop the first contour curve A and the second contour curve B into one straight line as shown in FIG. 8 to determine entire lengths of the first and second contour curves A and B which are closed curve to allow the respective entire lengths of the first and second contour curves A and B to be length A and length B, respectively.

[0039]

Then, at step S2, sampling intervals of the entire length A of the first contour curve A and the entire length B of the second contour curve B are determined. Namely, such an approach is employed to compare magnitudes (sizes) of the length A and the length B shown at step S11 of Fig. 9 and to locate the sampling points at the length interval which was resulted from dividing one longer in length by constant of the sampling interval. In this case, constant of the sampling interval is sampling interval where there can be obtained the number of points necessary for processing for re-constructing curve which will be described later at processing for generating such intermediate shape. Then, at step S12 of Fig. 9, at such an approach is employed to divide smaller one of magnitudes of length A and length B by the number of points within the section determined at the step S11 to obtain sampling interval. For this reason, sampling intervals less than the maximum sampling interval with respect to

both curves at all times can be obtained.

[0040]

Returning to FIG. 7, at step S3, resampling processing of curve A and curve B are carried out at sampling intervals determined at the step S2 to prepare point trains. Such state is shown in FIG. 10. Resampling processing are carried out with respect to the first contour curve A and the second contour curve B shown in FIG. 10 where sampling intervals are obtained. In this case, points on segment of one Bezier curve can be represented as a function of time t as described below.

$$Q(t) = ((1-t)^3)M + 3t(1-t)^2)N + 3(t^2)(1-t)O + (t^3)P \quad (0 \leq t \leq 1)$$

In the above formula, M, N, O, P are coordinates indicating points on the two-dimensional plane, wherein M, P are end points of line segment, and N, O are control points. Further, in order to represent, by t, points on the Bezier curve constituted by connecting plural segments, definition of the Bezier curve is extended to allow the integral part of t to be segment No. and to allow the decimal part of t to be time within segment. Namely, in the case of t=3.45, this indicates coordinate on the curve of the third segment and at time of 0.45. Thus, points on the Bezier curve constituted by plural segments are represented by t.

[0041]

Moreover, detailed flowchart of resampling processing carried out at the step S3 of FIG. 7 is shown in FIG. 11. At step S21, when resampling processing is carried out, times at correspondence points of the first contour curve A and the second contour

curve B shown in FIG. 10 are set as  $T_a$  and  $T_b$ . At the subsequent step S22, coordinates of points on the first contour curve A and the second contour curve B at times  $T_a$ ,  $T_b$  are determined. Respective points determined here result in sampling points at the first contour curve A and the second contour curve B. At the subsequent step S23, sampling interval determined at the above-described step S2 of FIG. 7 is added to times  $T_a$ ,  $T_b$ . At the subsequent step S24, there is judged whether or not times  $T_a$ ,  $T_b$  reach terminating ends so that correspondence points return to correspondence points at the time of start of resampling processing. Further, when it is judged that correspondence point returns to correspondence point at the time of start, the processing is completed. On the other hand, when it is judged that correspondence point does not return to the correspondence point, the processing returns to step S22 to repeat processing of the above-described steps S22 to S24 to set, for a second time, sampling points at the first contour curve A and the second contour curve B to generate point train consisting of sampling points. Namely, in the resampling processing of the step S3 of FIG. 7, there are generated point train corresponding to the first contour curve A and point trains corresponding to the second contour curve B which consist of sampling points finer than those at the above-described sampling processing.

[0042]

Further, returning to FIG. 7, at step S4, such an approach is employed to carry out interpolation calculation of coordinates of point trains on two curves prepared at

the previously mentioned step S3 to thereby determine point train of intermediate shape. In more detail, processing shown in flowchart of FIG. 12 is carried out to thereby generate intermediate curve indicating intermediate shape when there takes place change from the contour shape that the first contour curve A indicates to contour shape that the second contour curve B indicates. In accordance with the flowchart of FIG. 12, first, at step S31, point train corresponding to the first contour curve A and point train corresponding to the second contour curve B which are determined by resampling processing of the step S3 of FIG. 7 are inputted from the data memory 4. Further, there are designated sampling points at positions corresponding to correspondence points on point train corresponding to the first contour curve A and point train corresponding to the second contour curve B from the correspondence points. At the subsequent step S32, when time at which interpolation of two curves is carried out is assumed to be T with respect to point train consisting of sampling points, coordinate of point on the first contour curve A is assumed to be a, and coordinate of point on the second contour curve B corresponding to the coordinate a is assumed to be b, coordinate C of the point at intermediate curve indicating the intermediate shape to be determined is expressed by the following formula (2).

$$C = T \cdot a + (1-T) \cdot b \quad (2)$$

Namely, by applying the above-mentioned formula (2) to point trains corresponding to first and second contour curves, coordinate of sampling points constituting intermediate curve is determined from sampling points corresponding to the first

contour curve A and sampling points corresponding to the second contour curve B corresponding to sampling points corresponding to the first contour curve A. At the subsequent step S33, processing for designating next sampling points of the sampling points where the formula (2) is applied at the above-described step S32 is carried out with respect to point train corresponding the first contour curve A and point train corresponding to the second contour curve B. At the subsequent step S34, the arithmetic processing unit 2 judges whether or not correspondence point returns to the correspondence point where generation processing of intermediate curve is started at the above-described step S31 as the result of the fact that next sampling point is designated at the above-described step S33. Further, when it is judged that correspondence point returns to the corresponding point, the processing proceeds to step S35. On the other hand, when it is judged that correspondence points does not return to the correspondence point, the processing which has been explained at the step S32 is carried out with respect to sampling points designated at the step S33. Namely, the processing which has been explained at the step S32 is carried out with respect to all of sampling points set at the above-described sampling processing of the step S3 to thereby determine coordinate of points at the intermediate curve in accordance with the above-mentioned formula (2). At step S35, by using sampling points determined at the above-described step S3 and coordinate C of point at the intermediate curve determined at the step S32, the technology shown in the Japanese Patent Application Laid Open No. 164436/1998 publication or “An Algorithm for Automatically Fitting

Digitized Curves (pp. 612-626) in the “Graphics Gems” (Andrew S. Glassner) is applied to thereby transform (convert) point train consisting of sampling points into Bezier curve. Thus, curve is reconstructed from point train consisting of sampling points corresponding to first contour curve A and point train consisting of sampling points corresponding to the second contour curve B to generate intermediate curve indicating intermediate shape when change from first contour curve A to second contour curve B takes place as shown in FIG. 6.

[0043]

The curve generating apparatus 1 for carrying out such an intermediate curve generation processing is adapted so that when, as shown in FIG. 5, intermediate curve when there takes place change from the first contour curve A to the second contour curve B is generated, even if the numbers of segments of the first contour curve A and the second contour curve B are different from each other, the first and second contour curves are caused to undergo sampling to set the same number of sampling points with respect to the first contour curve A and the second contour curve B to re-construct curve. Accordingly, it is possible to generate intermediate curve as shown in FIG. 6 with high quality and simply.

[0044]

Here, returning to FIG. 3, at step S104, interpolated shape determined at step S103 is deformed in correspondence with reference correspondence points determined at the step S102. Explanation will be given with reference to FIGS. 13, 14 and 15 with

respect to such an operation.

[0045]

First, at step S41 of FIG. 13, start point 115 and end point 116 are caused to correspond to each other with respect to reference correspondence points 110 indicated at START of FIG. 14 determined by image pursuit processing of the step S102 of FIG. 3 and reference correspondence points 100 indicated at START of FIG. 14 determined at the intermediate shape preparation processing of the step S103. It is now assumed that coordinates of start points at the step S103 are A (ex1, ey1) and B(ex2, ey2) and coordinates of end points at the step S102 are C(sx1, sy1) and D(sx2, sy2). At the step S42, such a coordinate transformation (conversion) to convert line segment AB into line segment CD is determined. Such a transformation can be represented by combination of parallel displacement and rotation, and operation of scaling. Such a transformation is called affine transformation 120.

[0046]

The transform formula of affine transformation is as follows.

[0047]

With respect to the method of transforming point (x, y) into point (x', y') by the affine transformation, the following relational expression is assumed to hold.

$$[x'] = sc * [\cos\theta - \sin\theta][x - ex1] + [sx1]$$

$$[y'] = sc * [\sin\theta - \cos\theta][y - ey1] + [sy1]$$

[0048]

In the above formula,  $sc = L1/L2$

$$L1 = \sqrt{(sx2-sx1)^2 + (sy2-sy1)^2}$$

$$L2 = \sqrt{(ex2-ex1)^2 + (ey2-ey1)^2}$$

$$\theta = \theta_2 - \theta_1$$

$$\theta_1 = \tan^{-1} \left( \frac{(sy2-sy1)}{L1}, \frac{(sx2-sx1)}{L1} \right)$$

$$\theta_2 = \tan^{-1} \left( \frac{(ey2-ey1)}{L1}, \frac{(ex2-ex1)}{L1} \right)$$

[0049]

Then, at the step S43, affine transformation determined at the step S42 is calculated with respect to point train constituting intermediate shape determined at the step S102 of FIG. 3. As a result, there is prepared shape which holds feature of intermediate shape determined at the step S103 and passing through end point determined at the step 102. Then, at step S44, by using the method of transforming (converting) point train determined at step S43 into the previously described Bezier curve, transformation into curve is carried out. By carrying out such a processing with respect to all sections of shape, it becomes possible to transform shape prepared at the intermediate shape preparation processing of the step S103 into shape passing through reference correspondence points prepared at the step S102.

[0050]

As described above, in accordance with this invention, in preparing intermediate shape of two curves, it becomes possible to prepare intermediate shape passing through designated reference correspondence points. In addition, it is possible to set

reference correspondence point at precise position by image pursuit processing. As a result, it has become possible to prepare, with high precision, intermediate shape determined at picture image designated on the time axis. Thus, positional shift between shape by linear interpolation and actually determined shape which was the problem of the prior art can be solved.

[0051]

Another more practical example of this invention will now be described. In FIG. 16, there is shown the example in which the step S103 is omitted among the condition of the first embodiment shown in FIG. 3 and the portion of the step S104 is realized by another method as step S105.

[0052]

Edge information of picture image is used as substitutive means for preparing intermediate shape to carry out processing for automatically generating shape passing through the reference correspondence point and along the edge. In more practical sense, as a method of detecting optimum path passing through the designated point, there is used the technology of path search method disclosed in the Japanese Patent Application No. 204862/1997 by the applicant of this application.

[0053]

Explanation will be first given in connection with curve generating means which generates curve by the path search method disclosed in the Japanese Patent Application No. 204862/1997.

[0054]

FIG. 17 is a block diagram showing curve generating means. The curve generating means is composed of respective processing means composed of two point selector means 151, path search processing optimization means 152, path search means 153 and curve approximate means 154, and respective data stores (storages) 16, 17, 23, 18 for point train, picture image, path and curve.

[0055]

The two point selector means 151 selects successive two points from the point train data storage means 16 to output them. The path search processing optimization means 152 calculates path search parameter for optimizing the path search method from the selected two points and picture image data from the picture data storage means 17 to send it to the path search means 153.

[0056]

The path search means 153 determines path search processing method on the basis of the path search parameter that the path search processing optimization means 152 has calculated to calculate path connecting the selected two points and passing on the contour within picture image to hold it by the path data storage means 23.

[0057]

In this case, path data is list of pixel coordinates indicating eight vicinity graphics connecting the above-mentioned two points. As indicated by broken lines in FIG. 17, the path search means 153 sends control information to the two point selector

means 151 to select the next two points. Accordingly, path searches are carried out with respect to portions between respective points of the point train storage means 16 so that all the search data are accumulated (stored) into the path data storage means 23.

[0058]

When the two point selector means 151 has selected until the last of the point train to fail to output new two points, it sends control information to the curve approximate means 154 as indicated by broken lines in FIG. 17 to hasten the operation of the curve approximate means 154. The curve approximate means 154 carries out curve approximation of path stored in the path data storage means 23 to prepare curve data indicating contour shape to hold it by the curve data storage means 18.

[0059]

Explanation will now be given with reference to FIGS. 18 and 17 in connection with path search method that the curve generating means executes.

[0060]

FIG. 18 is a flowchart showing fundamental processing procedure of the path search method according to this invention. First, at step S1, the two point selector means 151 selects successive two points from the point train data storage means 16 to output them.

[0061]

Then, at step S2, optimization of path search parameter is carried out. Path

search parameter is calculated by the path search processing optimization means 152 on the basis of the two points selected by the point selector means 151 and picture data.

[0062]

Then, at step S3, path search is carried out. The path search means 153 determines the path search method on the basis of path search parameter obtained at the second step S2 to extract contour connecting the above-mentioned two points in the form of 8 vicinity path.

[0063]

Further, at step S4, there is carried out judgment as to whether or not path searches between all relaying (repeating) points have been completed. As a result, if such path searches have not yet been completed, the processing returns to step S1 to select two points in which one point is shifted from the two points selected at last time to repeat steps S2, S3. On the other hand, when it is judged at step S4 that path searches between all relaying points have been completed, the processing proceeds to step S5.

[0064]

At the step S5, contour curve which approximates 8 vicinity path is generated to complete the processing. The curve approximate means 154 carries out curve approximation of path data stored in the path data storage means 23 to prepare curve data indicating contour shape.

[0065]

In this case, the curve approximate means 154 can be realized by the technology in which the applicant of this application has disclosed “Curve Generating Apparatus and Curve Generating Method” in the Japanese Patent Application Laid Open No. 303687/1996 publication. This technology is a method of obtaining curve which approximates coordinate list and is one of the so-called curve approximation methods. Namely, this method is method of approximating order of input data while dividing it within the sufficiently approximatable range so that this method is robust to noise and has good efficiency as compared to the conventional curve approximations.

[0066]

However, the above-mentioned curve approximation means 154 may be methods of curve-approximating a series of coordinate lists, and may be realized by a method of generating B-spline curve generally used, etc.

[0067]

It is to be noted that general curve approximation/interpolation methods are described in detail in articles such as “Numerical Calculation Handbook” (Yutaka Ohno, Kazuo Isoda, Ohm Company, 1990), “Shape Processing Engineering [I][II] by Computer Display” (Fujio Yamaguchi, Nikkan Kogyo Shinbun Sha, 1982, “Computer Graphics Principles and Practice” (Foly, vanDam, Feiner, and Hughes, Addison Wesley Company, 1990), etc.

[0068]

The path search processing optimization means 152 and the path search means 153 will now be described in more detail.

[0069]

FIG. 19 is a block diagram in which the portion for carrying out path search is extracted of the curve generating means. The feature of the curve generating means for carrying out this path search resides in that path search processing optimization means 152 is provided to thereby carry out path search processing optimized with respect to inputted two points. In this example, the path search processing optimization means 152 is adapted to output two kinds of path search parameters which will be described later.

[0070]

FIG. 20 shows the internal configuration of the path search processing optimization means 152. The path search processing optimization means 152 is composed of passing cost calculation range determining means 156 and passing cost calculation optimization means 157. The passing cost calculation range determining means 156 inputs selected two points to output calculation range parameter. Further, the passing cost calculation optimization means 157 outputs passing cost calculation parameter from the selected two points and picture data. In addition, these two kinds of path search parameters are inputted to the path search means 153 and are used for determining the path search method.

[0071]

FIG. 21 is a flowchart showing processing procedure at the path search processing optimization means 152.

[0072]

First, at step S11, optimization of passing cost calculation parameter is carried out. In the passing cost calculation optimization means 157 calculates passing cost calculation parameter from the selected two points (point 1 and point 2) and picture image. Then, at step S12, optimization of the passing cost calculation range parameter is carried out to complete the processing. The passing cost calculation range determining means 156 inputs selected two points to calculate calculation range parameter.

[0073]

FIG. 22 is a block diagram showing, in more detail, the portion for carrying out processing relating to passing cost calculation parameter in FIG. 20.

[0074]

The passing cost calculation optimization means 157 is caused to be of configuration comprising gradient parameter determining means 158.

[0075]

Moreover, the path search means 153 is caused to be of configuration comprising passing cost calculation means 159, minimum cost path calculating means 161, and passing cost map storage means 160 for storing data called passage cost map which will be described later.

[0076]

The gradient parameter determining means 158 inputs picture data and two points to calculate gradient parameter optimum for extracting contour between the two points to output it to the passing cost calculating means 159 of the path search means 153.

[0077]

The passing cost calculating means 159 inputs picture data, the point 1, the gradient parameter, and calculation range parameter that the passing cost calculation range determining means 156 shown in FIG. 20 outputs to calculate passing cost map.

[0078]

The minimum cost path calculating means 161 inputs passing cost map and the point 2 to calculate path connecting the points 1 and 2 so as to trace the contour therebetween.

[0079]

FIG. 23 is a flowchart showing processing procedure at the path search means 153.

[0080]

First, at step S21, the passing cost calculating means 159 described later calculates passing cost map. Then, at step S22, the minimum cost path calculating means 161 calculates the minimum cost path. The detail of this operation will be described later.

[0081]

FIG. 24 shows, in more detail, the configuration of the portion for carrying out processing relating to the above-described passing cost calculation parameter.

[0082]

The passing cost calculation parameter is two kinds of parameters necessary in calculating gradient of picture image. The first parameter is normal vector indicating direction perpendicular to advancing direction of contour, and the second parameter is pixel value color change vector indicating change of pixel value when observed in a direction traversing the contour.

[0083]

Moreover, the path search means 153 carries out a processing to extract, by utilizing the fact that object contour has high gradient strength, such a path on the picture image to pass as close as possible the portion having higher gradient strength.

[0084]

In order to carry out processing as described above, the pass cost calculating means 159 is composed of gradient calculating means 164, passing cost map calculating means 165 and gradient data storage means 21.

[0085]

The gradient calculating means 164 calculates gradient of picture image, and the passing cost map calculating means 165 calculates passing cost map such that when path is passed through the portion where gradient strength is higher, cost is

reduced to more degree on the basis of the gradient thus obtained. Position of the point 1 is inputted to the passing cost map calculating means 165 and starting point of the passing cost map is set at the point 1.

[0086]

In this example, the gradient calculating means 164 selectively detects only gradient component of necessary contour by using the technology in which the applicant of this application has disclosed in “Edge Detection Method and Edge Detection Apparatus” in the Japanese Patent Application Laid Open No. 134420/1995 publication. By this gradient calculating means 164, gradient is calculated so as to selectively extract gradient of contour extending in a manner connecting inputted two points.

[0087]

Explanation will now be given in detail in connection with calculation process of the above-described two kinds of path search parameters.

[0088]

First, calculation of passing cost calculation parameter and the process where such parameter is utilized will be described. FIG. 25 is a flowchart showing processing procedure at the gradient parameter determining means 158. At step S31, normal vector calculating means 162 calculates normal vector perpendicular to the direction connecting inputted points 1 and 2 to output it. At step S32, pixel value change vector calculating means calculates change of pixel value of picture image

when observed in a direction perpendicular to the direction connecting two points, e.g., color change direction in the neighboring region of the points 1 and 2 on the picture image to output it as color change vector.

[0089]

In this example, the passing cost map is information in which, in each pixel, direction admitted to that pixel position at minimum passing cost is recorded.

[0090]

FIG. 26 shows an example of simple passing cost map.

[0091]

The passing cost map is prepared with respect to one range within picture image designated by the passing cost calculation range parameter. In this example, there is shown an example where such map is prepared in a certain small quadrilateral region.

[0092]

In FIG. 26(A), directions admitted to that pixel position at the minimum passing cost in the respective pixels are indicated by arrow. This direction is calculated so that only one direction is determined in each pixel. Value labeled at each pixel is accumulated value of passing cost when admitted in accordance with the minimum passing cost direction. This accumulated value is determined by allowing point 1 serving as starting point of path search as accumulated value 0.

[0093]

FIG. 26(B) shows process where minimum path calculating means 161

determines path when passing cost map is obtained as shown in FIG. 26(A).

[0094]

The minimum cost calculating means 161 inputs passing cost map and the point 2 to trace, in an opposite direction, minimum passing cost direction of the passing cost map from the point 2 to thereby determine path of the minimum cost ranging from the point 1 to the point 2. For example, in the case where the point 2 is located at position shown in FIG. 26(B) (accumulated cost is 22), the arrows are traced from the point 2 (written in a direction opposite to that in FIG. 26(A)) to determine path until the point 1 as indicated by slanting lines.

[0095]

Explanation will now be given in connection with means for calculating passing cost map as described above at a high speed. Calculation of passing cost map is generally known as a sort of optimization problem, and a method of calculating such a cost map by using dynamic programming, etc. is well known. Also in the previously described article “Intelligent Scissors for Image Composition,” a method using dynamic programming is described.

[0096]

FIG. 27 shows an example of description relating to shortest path search algorithm using dynamic programming. It is to be noted that, in this description, signs, etc.. are partially changed from the program described in the above-mentioned article “Intelligent Scissors for Image Composition”.

[0097]

Calculation of calculation range parameter and process where such parameter is utilized will now be described.

[0098]

FIG. 28 is a block diagram showing, in more detail, the portion for carrying out processing relating to calculation range parameter in FIG. 20.

[0099]

The passing cost calculation range determining means 156 is caused to be of configuration comprising distance calculating means 167, calculation range width calculating means 168, calculation range length calculating means 169, and calculation range calculating means 170.

[0100]

The distance calculating means 167 inputs points 1 and 2 to calculate distance between the two points and direction connecting the two points. The calculation range length calculating means 169 inputs the distance between the two points obtained to calculate calculation range length. The calculation range width calculating means 168 inputs distance between the two points obtained to calculate calculation range width. The calculation range calculating means 170 calculates calculation range parameter to determine shape of the calculation range on the basis of the above-mentioned calculation range length, calculation range width and direction connecting two points that the distance calculating means 167 has outputted to input it to the passing cost

calculation means 159 of the path search means 153. The passing cost calculation means 159 calculates passing cost map within the range indicated by the calculation range parameter.

[0101]

FIG. 29 is a flowchart showing processing procedure at the passing cost calculation range determining means 156 of FIG. 28.

[0102]

First, at step S41, the distance calculating means 167 inputs points 1 and 2 to calculate distance between these two points and direction connecting two points.

[0103]

Then, at step S42, the distance between the two points is inputted. Thus, calculation range width is calculated. In this case, the calculation range width calculating means 168 has therein rule of magnitude (size) of calculation range width with respect to magnitude (size) of distance between two points in the form such as calculation formula or reference table, etc. to determine calculation range width in accordance with that rule. For example, the problem in which even if operator attempts to set relaying (repeating) points in detail at short intervals in order to obtain a desired contour, searched path is meandered between relaying points so that shape differs from desired shape of contour can be solved by employing a rule such that the rule for determining calculation range width changes to a rule such that according as distance between two points becomes smaller, width becomes smaller.

[0104]

At this time, calculation range width between relaying (repeating) points set in detail at short intervals is set so that it becomes very narrow, and path search is carried out so that relaying (repeating) points are connected by substantially straight line. Thus, contour shape that operator desires is obtained.

[0105]

Then, at step S43, the calculation range length calculating means 169 calculates calculation range length from distance between two points. In this case, the calculation range length is determined so that it is larger than the distance between two points by margin length determined in advance.

[0106]

Finally, at step S44, the calculation range calculating means 170 calculates calculation range parameter from the calculation range width, the calculation range length and direction connecting two points. In this case, the calculation range is such a rectangle to surround inputted two points and inclined in the direction connecting two points, and the calculation range parameter indicates positions of four corners of that rectangle.

[0107]

The point train generating means 12 will now be described.

[0108]

The point train generating means 12 inputs curve to output point train

reproducing that shape and reconstructed curve reconstructed by that point train. The point train and the reconstructed curve which have been generated are used for curve editing work which will be carried out later by the configuration of the first embodiment.

[0109]

FIG. 30 is a block diagram showing an example of the configuration of the point train generating means 12.

[0110]

This point train generating means 12 is caused to be of configuration comprising initial point train generating means 171, curve reconstructing means 172, difference detecting means 173, point train editing means 14, picture image data storage means 17, point train data storage means 16, and reconstructed curve data storage means 19.

[0111]

The initial point train generating means 171 inputs input curve and picture image to generate initial point train. The point train is stored in the point train data storage means 16. The curve reconstructing means 172 inputs point train and picture image to generate such a curve to pass the point train and to pass on the contour of the picture image.

[0112]

The difference detecting means 173 inputs input curve and re-constructed curve

to output difference between both shapes as difference. The point train editing means 14 operates point train data in the point train data storage means 16 on the basis of difference that the difference detecting means 173 has outputted.

[0113]

FIG. 31 is a flowchart showing processing procedure in the point train generating means 12.

[0114]

First, at step S51, the initial point train generating means 171 carries out extraction of feature points of input curve to store the extracted feature points into the point train data storage means 16 as initial point train.

[0115]

For the above-mentioned feature point extraction on the curve, there may be used feature point extraction method shown in "Motion Vector Estimation Method" described in the Japanese Patent Application Laid Open No. 335270/1996 publication. In accordance with this method, such an approach is employed to calculate very small section bending angles at respective points from the initial end to the terminating end of curve to allow its sum total to be accumulated bending angle, whereby when the accumulated bending angle is greater than a threshold value determined in advance, the point which takes the maximum very small section bending angle is caused to be feature point. Further, similar feature point extraction processing is recursively carried out with respect to curve divided by feature points.

[0116]

Then, at step S52, the curve re-constructing means 172 calculates re-constructed curve by processing similar to the processing in the previously described path search apparatus according to this invention from the point train.

[0117]

Then, at step S53, the difference detecting means 173 calculates difference between input curve and re-constructed curve. In accordance with such difference detection processing, such an approach is employed to take difference detection points at suitable intervals on the re-constructed curve to measure distance up to input curve from that difference detection point to allow it to be difference value.

[0118]

Then, at step S54, the difference detecting means 173 examines whether or not there exist difference value greater than threshold value set in advance. If there does not exist difference value greater than the threshold value, the processing of the point train generating means 12 is completed. Thus, data in the point train data storage means 16 and re-constructed curve data storage means 19 at that time point serve as output. On the other hand, if there exists difference value greater than the threshold value, the processing proceeds to step S55.

[0119]

At the step S55, the point train editing means 14 edits point train data on the basis of difference thus obtained. At respective difference detection points in which

it is judged that the difference value is greater than threshold value, new relaying (repeating) point is placed at point on the input curve nearest from that difference detection point to store point train data into the point train data storage means 16.

[0120]

After completion of the step S55, the processing returns to the step S52. Thus, at step S54, processing is repeated until difference between input curve and re-constructed curve becomes smaller than threshold value.

[0121]

While, in the above-mentioned processing, the number of points constituting initial point train is set to lesser value at first to suitably supplement initial points at the shortage portions, there may be employed a method in which the number of points constituting initial point train is set to larger value to delete unnecessary points. In that case, such an approach may be employed to generate initial point train to such a degree that input curve can be sufficiently polygon-approximated by the initial point train generating means 171 to select and delete relaying (repeating) points in which difference value therearound is sufficiently smaller than threshold value by the difference detecting means 173 after re-construction of the curve.

[0122]

It is to be noted that while, in the processing procedure shown in FIG. 31, since re-construction can be completed by lesser number of points, there results the merit that curve editing thereafter is easy, processing procedure which will be described later

has the merit that because relaying (repeating) point interval for carrying out path search can be small, processing time can be shortened.

[0123]

Moreover, point train obtained by the above-mentioned method is transformed (converted) into curve by using curve generating means. Namely, by using edge information of picture image in preparing intermediate shape passing through portions between respective correspondence points by using the above-mentioned method, it has become possible to prepare contour having high precision along the shape represented in the picture image.

[0124]

Further, in the method shown in FIG. 16, such an approach may be employed to determine edge of picture image by using another algorithm at step S105 to determine intermediate shape along the edge of that picture image.

[0125]

Namely, at step S102, a set of correspondence points determined by picture image pursuit and the picture image are used to determine color projection axis which maximizes contrast around the edge to form edge of picture image by using such color projection axis to determine intermediate shape along this edge.

[0126]

The configuration of optimum color projection axis calculating unit which inputs the set of correspondence points as representative points 1 and 2 to determine

the color projection axis is shown in FIG. 32.

[0127]

The optimum color projection axis calculating unit 32 is composed of a representative point vicinity (neighboring) color projection axis calculating section 41 and a representative point vicinity (neighboring) optimum color projection axis calculating section 41 for calculating vicinity (neighboring) optimum color projection axes within the region in the vicinity of representative points 1 and 2, and a color projection axis synthesis section 42 for synthesizing color projection axis by using the color projection axis 1 and the color projection axis 2 from the above-mentioned two calculating sections 41 and 41.

[0128]

At the representative point vicinity (neighboring) optimum color projection axis calculating sections 41, there are determined vicinity (neighboring) optimum color projection axes which maximize contrast around the edge included within neighboring regions of representative points. It is now assumed that, as shown in FIG. 33, representative points 1 (p0) and 2 (p1) are determined. At this time, the representative point vicinity (neighboring) color projection axis calculating section 41 determines, by calculation, color projection axis (1) B0 in which the contrast is maximum of edge included within the neighboring region A1 of representative point p1. In addition, the representative point vicinity neighboring color projection axis calculating section 41 determines, by calculation, color projection axis (2) B1 in which the contrast is

maximum of edge included within the vicinity (neighboring) region A2 of the representative point p1.

[0129]

The color projection axis synthesis section 42 synthesizes vicinity (neighboring) optimum color projection axis (1) B0, vicinity (neighboring) optimum color projection axis (2) B1 respectively independently determined within the vicinity (neighboring) regions of representative points 1 and 2 to determine one color projection axis where the contrast is maximum of edge of updating section. As the synthesis method in this case, e.g., average vector of color projection axes may be axis after synthesis.

[0130]

In addition, the maximum color projection axis calculating section 32 may determine optimum color projection axis by the method shown in FIG. 34.

[0131]

As shown in FIG. 34(A), it is assumed that anchor point p0 and adjacent anchor point p1 are placed on edge of picture image. At this time, since there is the possibility that the edge may deviate to much degree from the line segment connecting p0 and p1, there is carried out search of region where color change is the greatest within the range of length H on the line segment in a direction perpendicular to p0p1 with respect to points q0, q1, and q2 placed every equal interval with respect to line segment length L on the line segment p0p1, e.g., interval of L/4.

[0132]

When color with respect to a certain point  $r$  is assumed to be  $C(r)$ , it is defined that color change vector is  $dC/dr$  and its magnitude is  $|dC/dr|$ . Thus,  $r$  in which this value takes the maximum value is determined.

[0133]

As the result of search,  $r0, r1, r2$  are assumed to be determined as shown in FIG. 34(B). At this time, color change vectors  $dC/dr$  are respectively determined at  $r0, r1, r2$  to allow its average value to be optimum color projection axis.

[0134]

In addition, color change vector may be determined in a manner described below. In the case of  $r0$ , colors  $C(s00), C(s01)$  are determined with respect to points  $s00, s01$  having  $r0$  as center and away from each other by distance width  $h$  on the straight line perpendicular to the line segment  $p0p1$ . Thus, color change vector is substituted for its difference vector  $\Delta C = C(s01) - C(s00)$ . In connection with  $r1, r2$ , color change vectors are respectively similarly determined.

[0135]

Ordinary contour closed curve generating unit generates contour closed curve on the basis of the optimum color projection axis which has been explained. At the step S105, intermediate shape based on this contour closed curve is prepared.

[0136]

In addition, when algorithm shown in FIG. 16 is deformed and linear interpolation at the step S102 fails to be carried out because, e.g., movement of picture

image is suddenly carried out, the processing of the step S105 may be carried out.

[0137]

As described above, in accordance with this invention, positional shift between shape by linear interpolation and shape actually determined, which was problem of the prior art, can be solved.

[0138]

[Effect of the Invention]

As previously mentioned, in accordance with this invention, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour. Thus, contour shape having higher precision can be prepared.

[Brief Description of the Drawings]

FIG. 1 is a block diagram showing configuration of a curve generating apparatus to which this invention is applied.

FIG. 2 is a view for explaining moving picture consisting of plural frames to be processed at the above-mentioned curve generating apparatus.

FIG. 3 is a flowchart showing processing procedure in software program relating to a curve generating method of this invention.

FIG. 4 is a view for explaining a method of carrying out pursuit by using absolute value sum of differences of picture images as pursuing method for picture image.

FIG. 5 is a view for explaining first contour curve A and second contour curve B used when intermediate curve is generated by the curve generating apparatus.

FIG. 6 is a view showing intermediate curve generated by the curve generating apparatus when there takes place change from first contour curve A to second contour curve B.

FIG. 7 is a flowchart showing processing of arithmetic processing unit when intermediate curve is generated and there takes place change from the first contour curve A to the second contour curve B.

FIG. 8 is a view for explaining that sampling points are set to determine sampling interval.

FIG. 9 is a flowchart showing processing when sampling intervals with respect to first contour curve A and second contour curve B are determined.

FIG. 10 is a view showing first contour curve A and second contour curve B from which sampling interval is obtained.

FIG. 11 is a flowchart showing processing when resampling processing is carried out.

FIG. 12 is a flowchart showing processing when there takes place change from first contour curve A to second contour curve B, sampling is required, and intermediate curve indicating intermediate shape is generated.

FIG. 13 is a flowchart for explaining processing procedure for deforming interpolated shape in correspondence with reference correspondence points.

FIG. 14 is a view showing a more practical example of processing up to step S42 of the flowchart shown in FIG. 13.

FIG. 15 is a view showing a more practical example of processing at the step S43 and steps subsequent thereto of the flowchart shown in FIG. 13.

FIG. 16 is a flowchart for explaining operation of another more practical example of this invention.

FIG. 17 is a block diagram showing an example of the configuration of the main part of curve generating means for generating curve by the more practical example of path search method which was disclosed in the Japanese Patent Application No. 204862/1997.

FIG. 18 is a flowchart showing basic processing procedure of the path search method.

FIG. 19 is a view for explaining the part for carrying out path search on the basis of the path search method.

FIG. 20 is a view for explaining internal configuration of path search processing optimization means.

FIG. 21 is a flowchart for explaining processing procedure in the path search processing optimization means.

FIG. 22 is a view for explaining the part for processing relating to passing cost calculation parameter of the path search processing optimization means.

FIG. 23 is a flowchart for explaining processing procedure in the path search

means.

FIG. 24 is a view for explaining, in detail, configuration of the part for processing relating to passing cost calculation parameter utilizing selective gradient detection.

FIG. 25 is a flowchart for explaining processing procedure in passing cost optimization means.

FIG. 26 is a view showing one example of passing cost map of path search.

FIG. 27 is a view showing one example of the shortest path search algorithm using dynamic programming.

FIG. 28 is a view for explaining in detail the part for processing relating to calculation range optimization of path search processing optimization means.

FIG. 29 is a flowchart for explaining processing procedure in calculation range optimization means.

FIG. 30 is a block diagram showing an example of the configuration of point train generating means.

FIG. 31 is a flowchart for explaining processing procedure in the point train generating means.

FIG. 32 is a block diagram showing the configuration of a more practical example of optimum color projection axis calculating unit for determining color projection axis.

FIG. 33 is a view for explaining the operation principle of a more practical

example of the optimum color projection axis calculating unit.

FIG. 34 is a view for explaining the operation principle of another more practical example of the optimum color projection axis calculating unit.

FIG. 35 is a view for explaining generating intermediate shape by interpolation processing from start frame and end frame in conventional technique of generating intermediate shape .

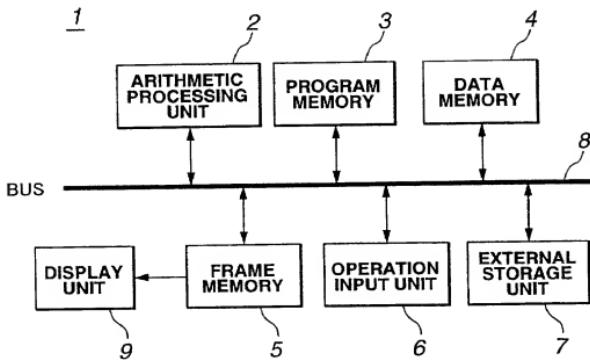
FIG. 36 is a view showing an example of line segment of third-order Beizer curve.

FIG. 37 is a view showing single curve indicating contour shape as plural segments.

[Explanation of Referenced Numerals]

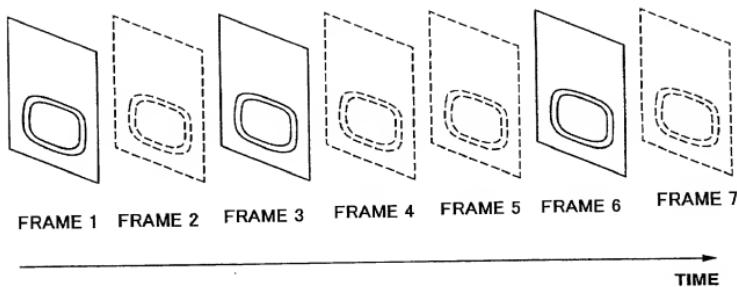
1 curve generating apparatus; 2 arithmetic processing unit

[FIG. 1]

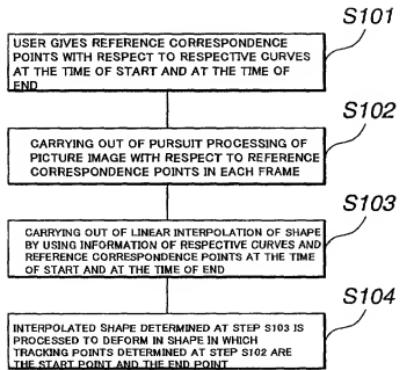


[FIG. 2]

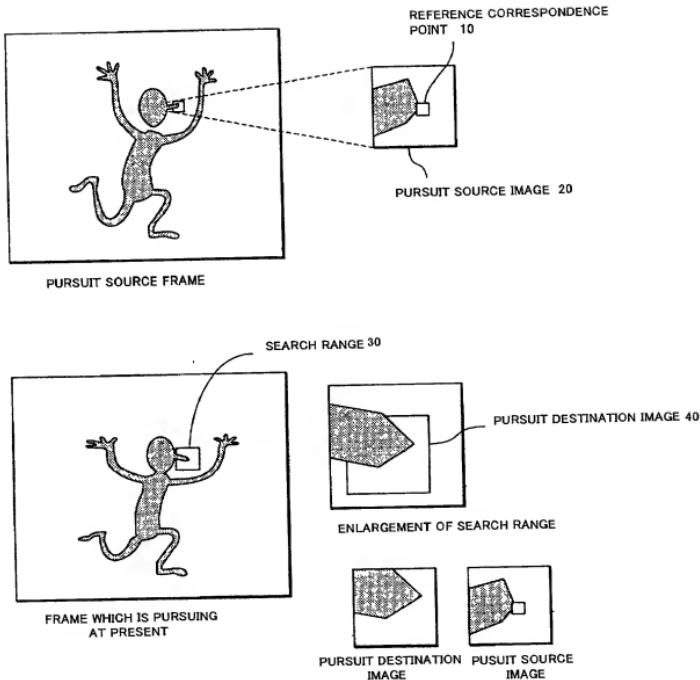
09673201-1234567890



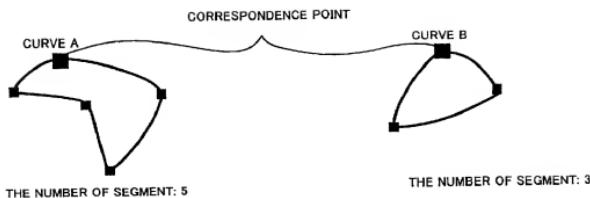
[FIG. 3]



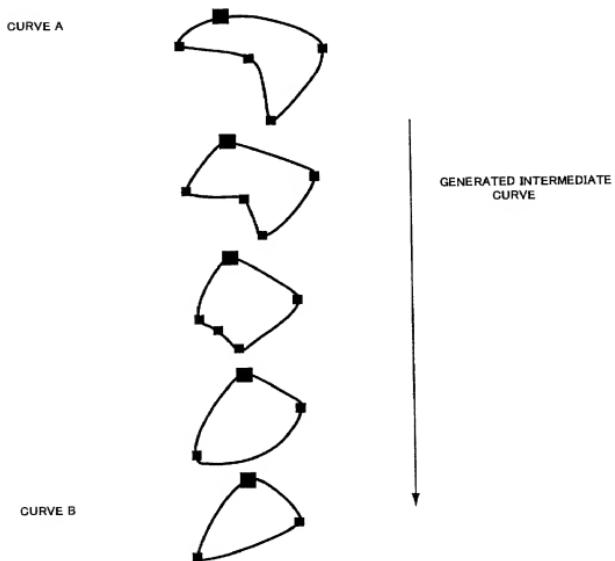
[FIG. 4]



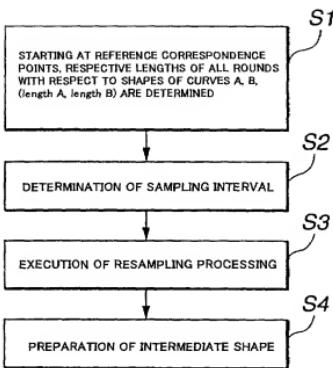
[FIG. 5]



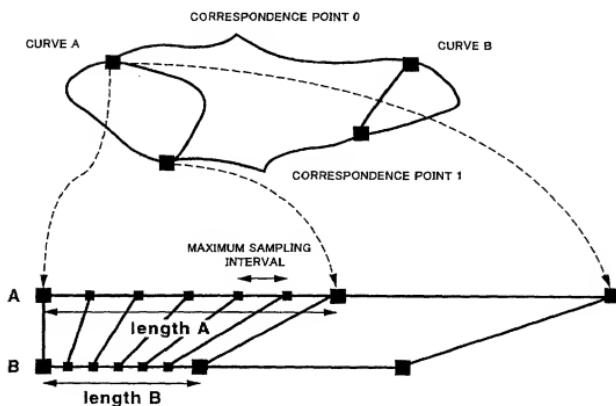
[FIG. 6]



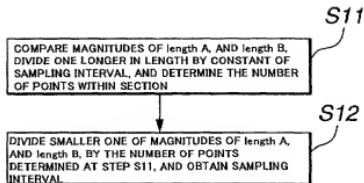
[FIG. 7]



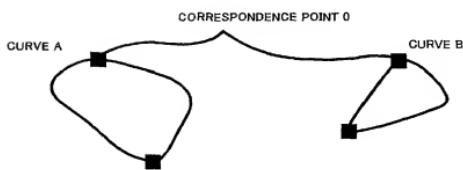
[FIG. 8]



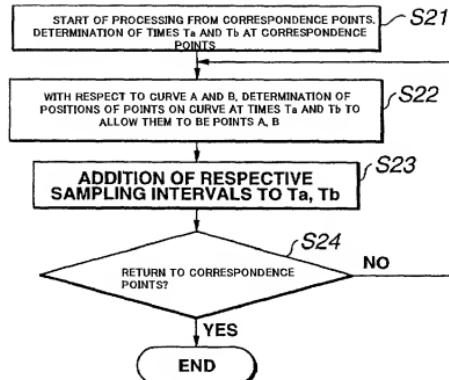
[FIG. 9]



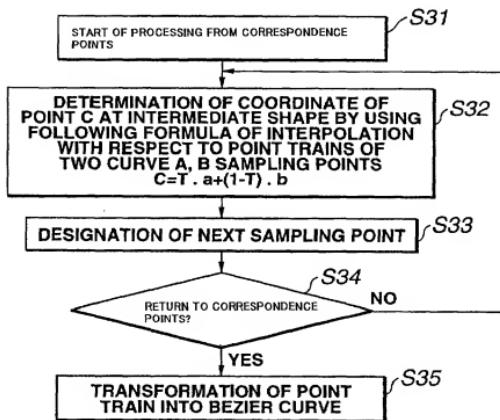
[FIG. 10]



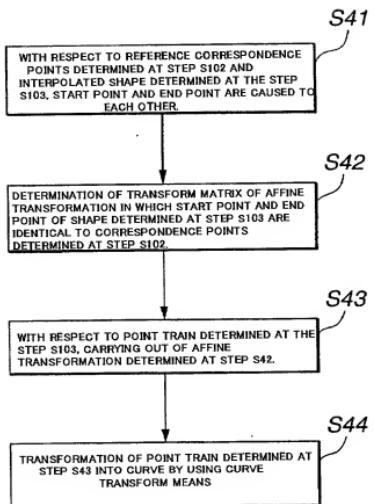
[FIG. 11]

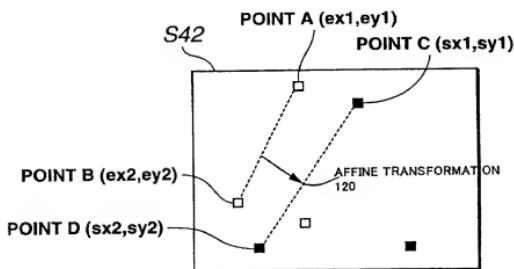
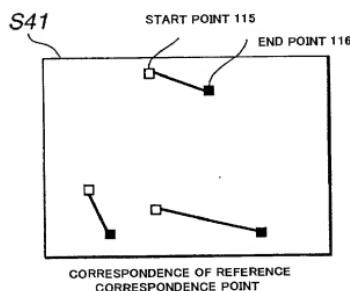
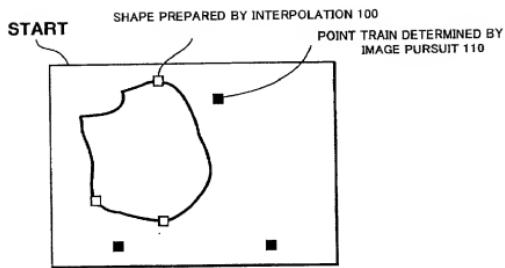


[FIG. 12]



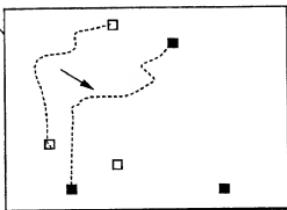
[FIG. 13]





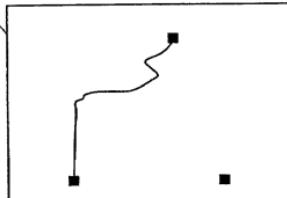
DETERMINE AFFINE TRANSFORMATION WHICH IS DEFORMED AS DESCRIBED ABOVE WITH RESPECT TO CORRESPONDENCE SECTION.

S43



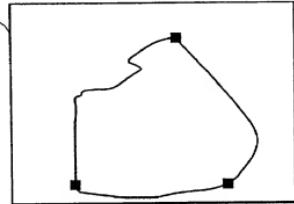
TRANSFORMING WITH RESPECT TO POINT TRAIN  
CONSTITUTING INTERMEDIATE SHAPE AS WELL

S44

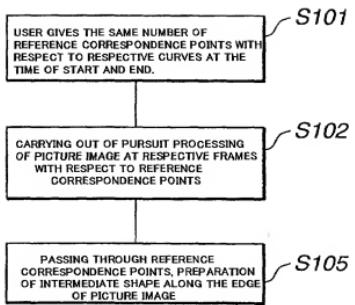


TRANSFORMING INTO BEZIER CURVE

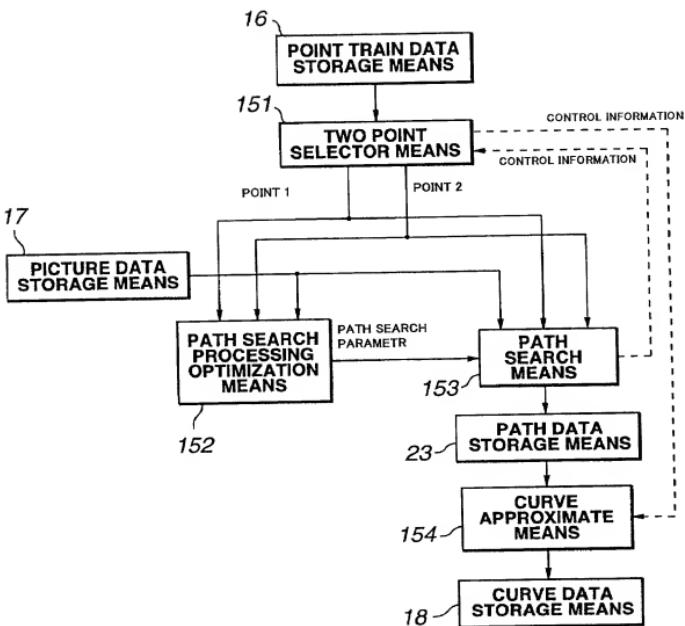
END



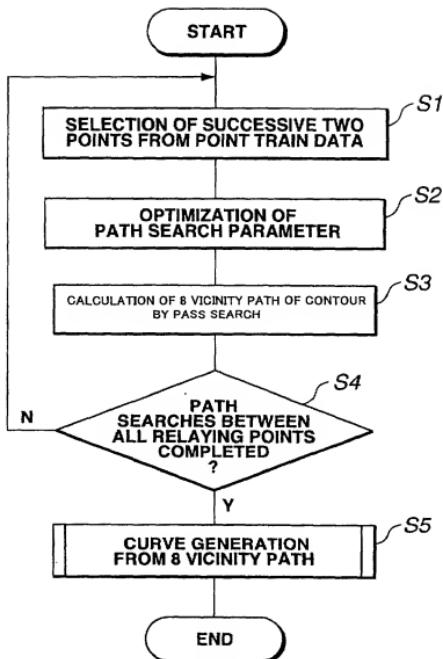
RESULT OF TRANSFORMING WITH RESPECT TO  
ALL SECTIONS



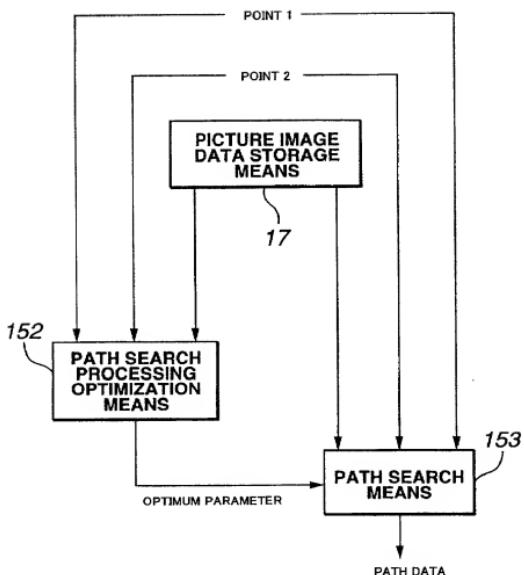
[FIG. 17]



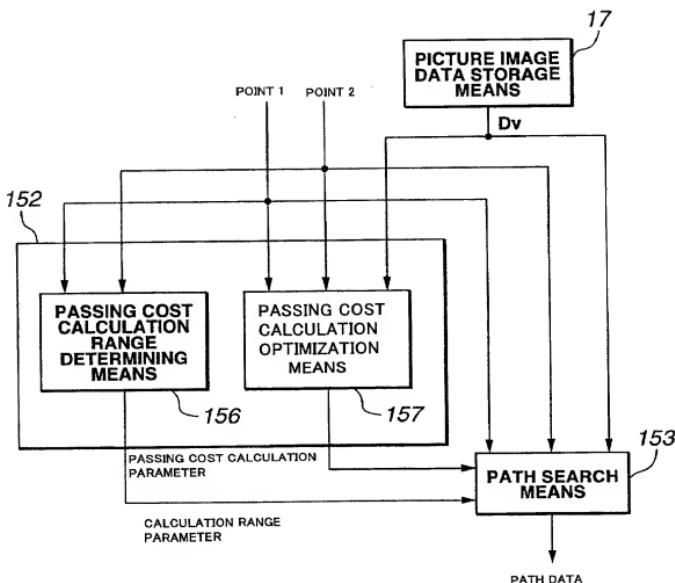
[FIG. 18]



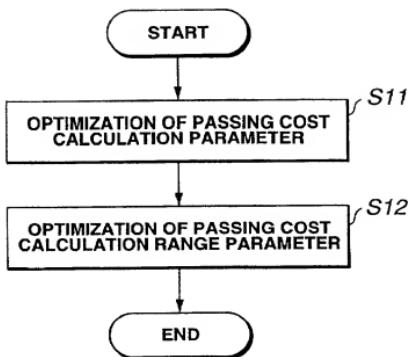
[FIG. 19]



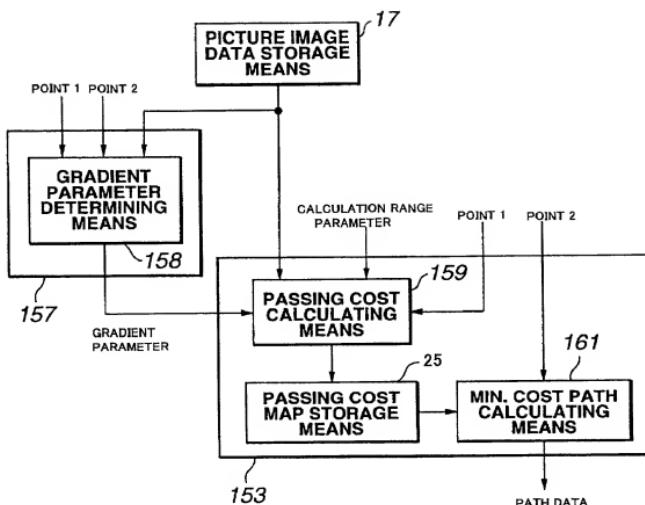
[FIG. 20]



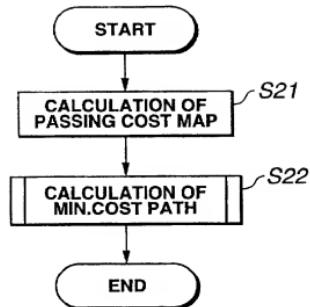
[FIG. 21]



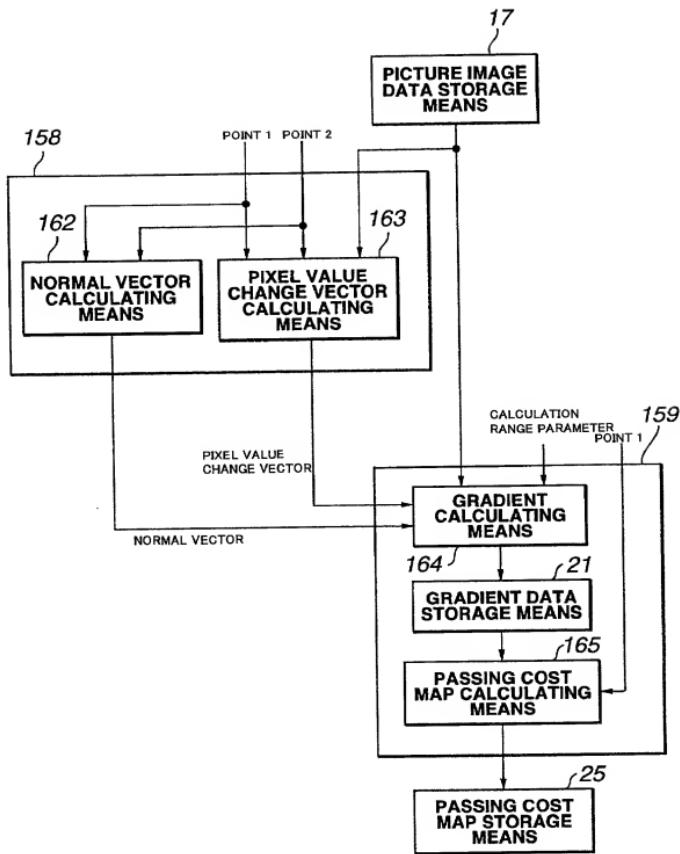
[FIG. 22]



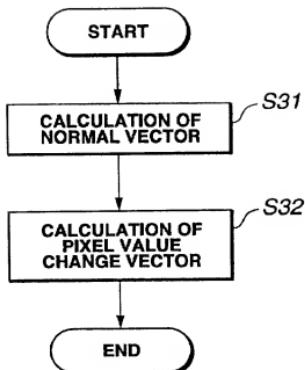
[FIG. 23]



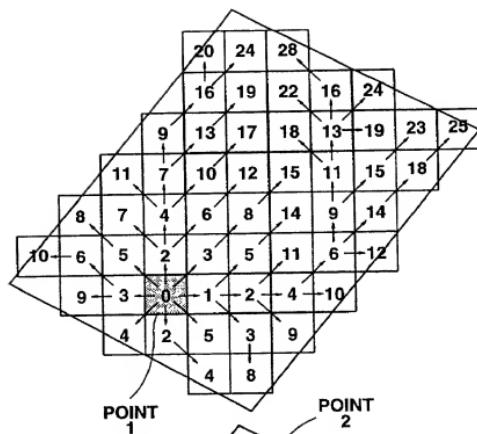
[FIG. 24]



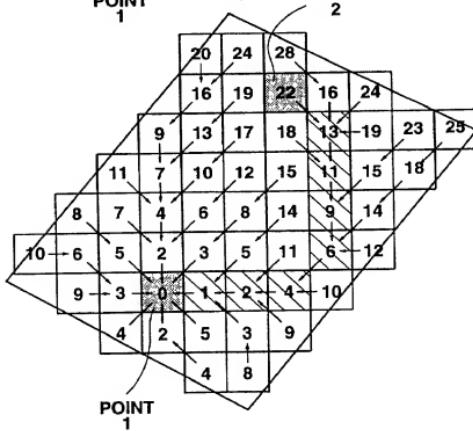
[FIG. 25]



(A)



(B)



The Live-Wire 2-D dynamic programming (DP) graph search algorithm is as follows:

Algorithm: Live-Wire 2-D DP graph search.

Input:

$s$  {Start(or seed) pixel.}  
 $l(q,r)$  {Local cost function for link between pixels q and r.}

Data Structures:

$L$  {List of active pixels sorted by total cost (initially empty.)}  
 $N(q)$  {Neighborhood set of q (contains 8 neighbors of pixel.)}  
 $e(q)$  {Boolean function indicating if q has been expanded/processed.}  
 $g(q)$  {Total cost function from seed point to q.}

Output:

$p$  {Pointers from each pixel indicating the minimum cost path.}

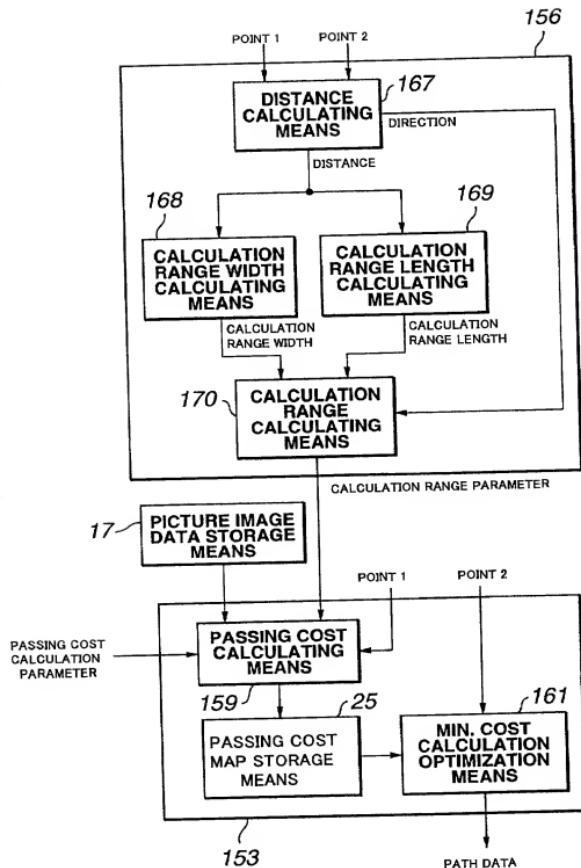
Algorithm:

```

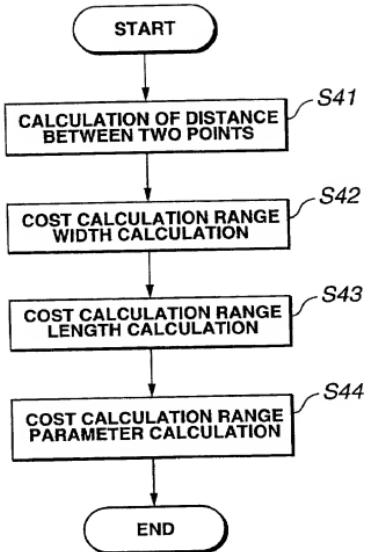
g(s)=0; L=s;                                {Initialize active list with zero cost seed pixel.}
while L!=NULL do begin                      {While still points to expand:}
  q=min(L)                                    {Remove minimum cost pixel q from active list.}
  e(q)=TRUE;                                  {Mark q as expanded(i.e.,processed.).}
  for each r in N(q) such that not e(r) do begin
    gtmp=g(q)+l(q,r);                         {Compute total cost to neighbor.}
    if r in L and gtmp < g(r) then             {Remove higher cost neighbor's}
      r=L;                                     {from list}
    if !(r in L) then begin
      g(r)=gtmp;                            {assign neighbor's total cost,}
      p(r)=q;                                {set (or reset) back pointer,}
      L=r;                                    {and place on (or return to)}
    end
  end
end

```

[FIG. 28]

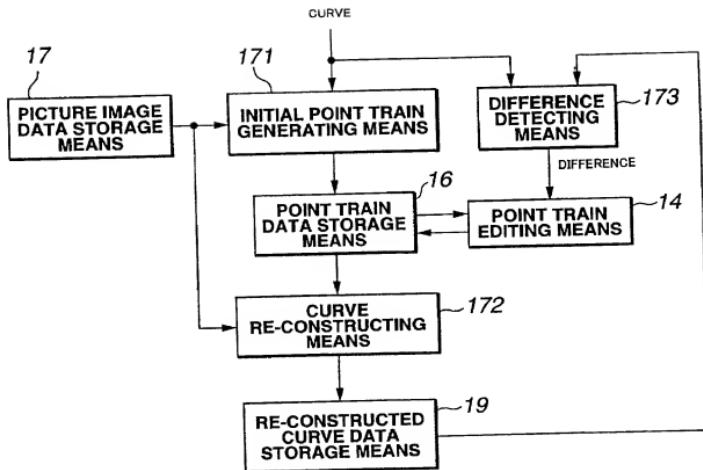


[FIG. 29]

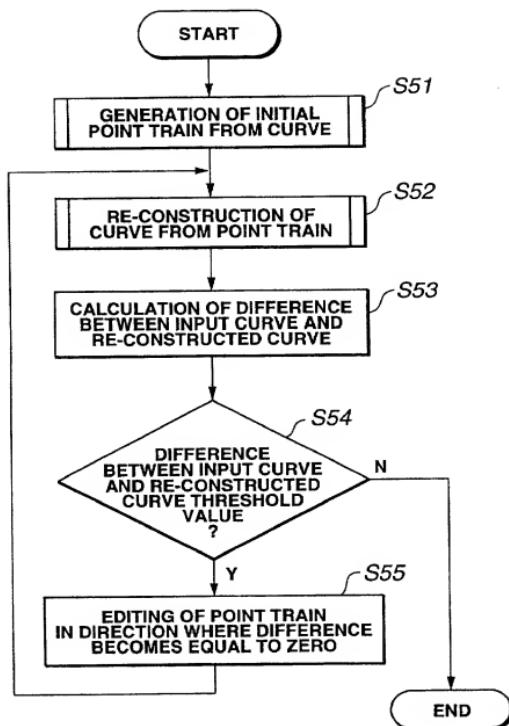


[FIG. 30]

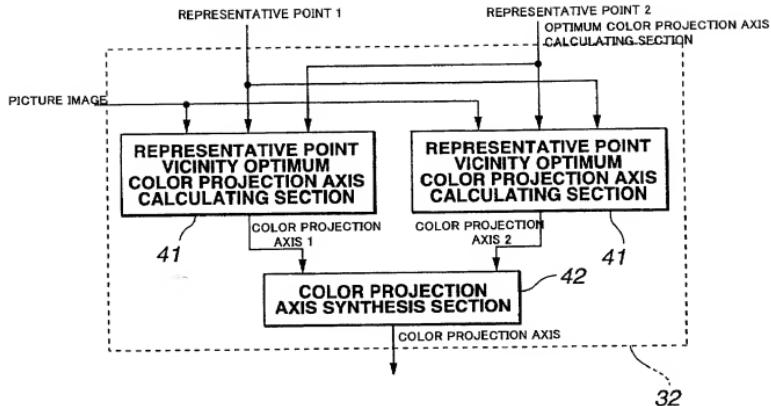
U.S. PATENT AND TRADEMARK OFFICE



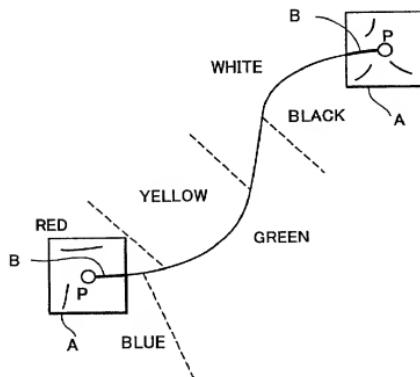
[FIG. 31]



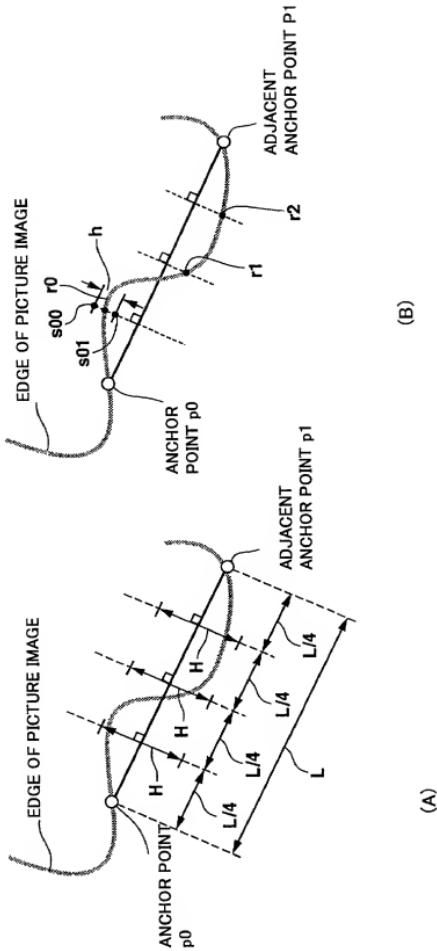
[FIG. 32]



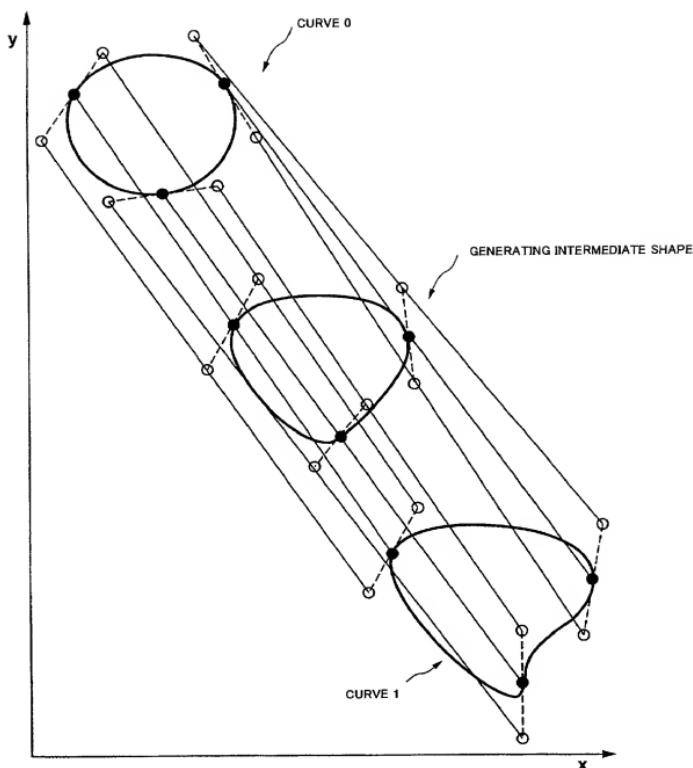
[FIG. 33]



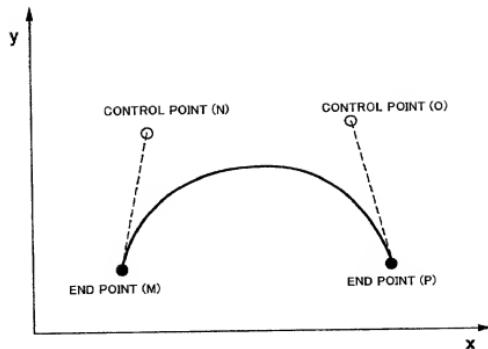
[FIG. 34]



[FIG. 35]

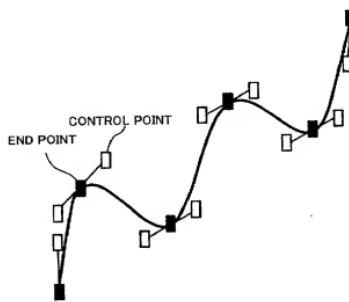


[FIG. 36]



Digitized by srujanika@gmail.com

[FIG. 37]



[Name of Document] ABSTRACT

[Summary]

422 Rec'd PCT/PTO 12 OCT 2008

[Task]

To provide a curve generating apparatus and a curve generating method in which in a process of generating intermediate shape of two curves, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour. Thus, contour shape with higher precision can be prepared.

[Means for Solution]

At step S101, user gives, as input, two curves at the time of start and at the time of end and reference correspondence points with respect to the respective curves. It is required that the numbers of reference correspondence points are the same with respect to the two curves. Then, at step S102, pursuit operation of reference correspondence point is carried out with respect to picture images successive in the time axis direction. As a result, positions of reference correspondence points at respective intermediate stages can be determined. Then, at step S103, interpolation of shape is carried out. Interpolation calculation of shape is employed to carry out interpolation calculation of coordinates of point trains on two curves to thereby determine coordinates of points of intermediate shapes. Then, at step S104, interpolated shape determined at the step S103 is deformed in correspondence with reference correspondence point determined by the pursuit operation at the step S102.

[Selected Drawing] Fig. 3

Information of Record for Applicant

Identification Number: [000002185]

1. Date of Change: August 30, 1990

[Reason of Change] Registration

[Address] 7-35, Kitashinagawa 6-chome,  
Shinagawa-ku, Tokyo, Japan

[Name] Sony Corporation

09/673202-1

31/prts.

09/673202

1

422 Rec'd PCT/PTO 12 OCT 2000

DESCRIPTION

Curve Generating Apparatus and Curve Generating Method, and Program  
Recording Medium

Technical Field

This invention relates to a curve generating apparatus and a curve generating method used in CAD (Computer Aided Design), CG (Computer Graphics), etc. which edit curve indicating contour shape of object included within picture image on the computer, and a program recording medium adapted so that program relating to the curve generating method is recorded.

Background Art

Hitherto, there are many instances where contour extraction processing for extracting contour shape of object included in plural picture image data constituting moving picture image are used in the field of picture image processing, e.g., CAD, CG technologies, etc. Among these picture image processing, when picture image synthesis processing is carried out, there is the processing which generates key signals from contour shape of the object, and it is important to generate precise or accurate key signals, i.e., precise contour shape. In this case, the key signal is information for cutting off the area of the foreground object to be synthesized and is also called mask.

The contour extraction processing is required to have interactive operability as in the case where operator gives in detail information such as contour position or direction, etc. with respect to object. As such contour extraction processing, there are processing to designate plural points on the contour of object to prepare shapes between respective points, processing to operate control points of parametric curve indicating counter shape, and processing to directly input contour shape by mouse, etc. As examples of these contour extraction processing, there are known "Intelligent Scissors for Image Composition" (Eric N. Mortensen and William A. Barrett, Computer Graphics Proceedings, Annual Conference Series, 1995, ACM SIGGRAPH, pp. 191-198), "Image contour detection method" (Japanese Patent Application Laid Open No. 152481/1992 publication), and "Cutting mask preparation method and cutting mask preparation apparatus" (Japanese Patent Application Laid Open No. 254854/1992 publication).

Moreover, in the contour extraction processing, it is required to extract precise contour shape with respect to all picture images constituting moving picture. For example, in cinemas or television picture images, several hundreds of key signals are required for generating images of several seconds, and the quantity of processing is vast. For this reason, the contour extraction processing used in the field of cinema, etc. is desired (required) that more precise contour shape can be prepared by lesser number of operations. This results from the fact that, in the conventional contour extraction processing, processing for preparing contour shapes with respect to

respective frames constituting moving picture is the processing which requires extremely much time and labor.

In view of the above, as a method of preparing contour shape by more simple procedure, there was proposed a method in which, on the premise that, in moving picture images having continuous property, contour shape at the start frame changes with passage of time so that it changes to contour shape at the end frame, intermediate shape of contour at the intermediate frame is prepared by interpolation processing from contour shape at the start frame and contour shape at the end frame.

In accordance with such an interpolation processing, as shown in FIG. 1, plural points constituting contour shape are caused to have one-to-one correspondence relationship at contour shape of the start frame and contour shape of the end frame. Namely, when it is assumed that curve indicating contour shape at the start frame (time  $t=0$ ) is curve  $C_0$ , curve indicating contour shape at the end frame (time  $t=1$ ) is curve  $C_1$ , and curve changes in point of time, it can be considered that curve  $C_0$  at time  $t=0$  changes to curve  $C_1$  at time  $t=1$ . In view of the above, when time  $t$  at which interpolation of two curves is assumed to be  $T$ , and coordinate at the point on the curve  $C_0$  is put by  $A$  and coordinate at the point on the curve  $C_1$  corresponding to the coordinate  $A$  is put by  $B$ , coordinate  $C$  at curve  $C_x$  which takes required intermediate form can be represented as follows.

$$C = T \cdot A + (1-T) \cdot B$$

In the conventional interpolation processing, contour curve  $C_x$  at the intermediate

frame ( $t=T$ ) was prepared from train of points determined by such interpolating calculation.

Further, it is assumed that contour shapes with respect to respective frames are constituted by plural third-order Bezier curve. The third-order Bezier curve is defined by

$$Q(t) = ((1-t)^3)M + 3t((1-t)^2)N + 3(t^2)(1-t)O + (t^3)P \quad (0 \leq t \leq 1)$$

as indicated by the article “Computer Graphics PRINCIPLE AND PRACTICE SECOND EDITION in C” (Foley, van Dam, Feiner, Hughes, ADDISON WESLEY, 1996, ISBN 0-201-84840-6). In this formula, M, N, O, P are coordinates indicating points on the two-dimensional plane wherein M and P are end points of line segment, and N, O are control points. An example of line segment of the third order Bezier curve represented by the above-mentioned formula is shown in FIG. 2. In FIG. 2, curve indicated by solid line is the third-order Bezier curve, wherein M, P indicated by points of black circle are end points, and points N, O indicated by white circle are control points.

In accordance with the formula which defines the above-described Bezier curve, locus of the third-order Bezier curve, i.e., shape is represented by coordinates of end points and control points indicated by points M, N, O, P and change of time t in FIG. 2.

When constituting unit of the third-order Bezier curve shown in FIG. 2 is assumed to be segment, it can be said that single curve indicating contour shape is

ordinarily composed of plural segments as shown in FIG. 3. In this case, end points of adjacent segments are shared so that one curve is constituted as the entirety.

In the above-described conventional contour extraction processing, in the case where intermediate shape is determined from contour shapes of frames before and after in point of time, interpolation was carried out in the state where control points R and end points S constituting segments in FIG. 3 are caused to have one-to-one correspondence relationship.

However, at frames before and after in point of time, there are instances where contour shape does not linearly move.

In the above-mentioned method, in the case where contour shape move non-linearly, shape different from contour shape was prepared.

In order to avoid such problems, it is conceivable to carry out work to divide interval in point of time between the time of start and the end time of end into narrower ranges to carry out interpolation processing of shape for a second time, or to manually modify the shape, etc. For this reason, there took place the problem that labour of user is required in preparing shape, and there takes place fine unevenness of shape because shape discontinuously changing is prepared in the time axis direction owing to manual modification.

#### Disclosure of the Invention

This invention has been made in view of actual circumstances as described

above, and its object is to provide a curve generating apparatus and a curve generating method in which, in the processing for preparing intermediate shape of two curves, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour, thus to prepare contour shapes with higher precision.

For this reason, the curve generating apparatus according to this invention is directed to a curve generating apparatus adapted for generating, from curve to be generated of first frame, curve at second frame, the apparatus comprising: correspondence point detecting means for determining, by using curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and curve generating means for generating curve of the second frame passing through correspondence points detected by the correspondence point detecting means..

Moreover, the curve generating method according to this invention is directed to a curve generating method for generating, from curve to be generated of the first frame, curve at second frame, the method comprising: a correspondence point detection step of determining, by using the curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and a curve generation step of generating curve of the second frame passing through the correspondence points detected by the correspondence detection step.

In addition, the program recording medium according to this invention is directed to a program providing medium for providing program relating to curve generation processing for generating, from curve to be generated of first frame, curve at second frame, wherein there is recorded program comprising: a correspondence point detecting step of determining, by using the curve to be generated of the first frame, correspondence points at the second frame corresponding to reference correspondence points set on the curve to be generated of the first frame; and a curve generation step of generating curve of the second frame passing through the correspondence points detected by the correspondence point detection step.

### Brief Description of the Drawings

FIG. 1 is a view for explaining a method of preparing shape of intermediate frame by interpolation processing from start frame and end frame.

FIG. 2 is a view showing an example of line segment of third-order Beizer curve.

FIG. 3 is a view showing single curve indicating contour shape as plural segments.

FIG. 4 is a block diagram showing configuration of a curve generating apparatus to which this invention is applied.

FIG. 5 is a view for explaining moving picture consisting of plural frames to be processed at the above-mentioned curve generating apparatus.

FIG. 6 is a flowchart showing processing procedure in software program relating to a curve generating method of this invention.

FIG. 7 is a view for explaining a method of carrying out pursuit by using absolute value sum of differences of picture images as pursuing method for picture image.

FIG. 8 is a view for explaining first contour curve A and second contour curve B used when intermediate curve is generated by the curve generating apparatus.

FIG. 9 is a view showing intermediate curve generated by the curve generating apparatus from first contour curve A and second contour curve B.

FIG. 10 is a flowchart showing processing when intermediate curve is generated from the first contour curve A and the second contour curve B.

FIG. 11 is a view for explaining that sampling points are set to determine sampling interval.

FIG. 12 is a flowchart showing processing when sampling intervals with respect to first contour curve A and second contour curve B are determined.

FIG. 13 is a view showing first contour curve A and second contour curve B from which sampling interval is obtained.

FIG. 14 is a flowchart showing processing when resampling processing is carried out.

FIG. 15 is a flowchart showing processing when intermediate curve indicating intermediate shape is generated.

FIG. 16 is a flowchart for explaining processing procedure for deforming interpolated shape in correspondence with reference correspondence points.

FIG. 17 is a view showing a more practical example of processing up to step S42 of the flowchart shown in FIG. 16.

FIG. 18 is a view showing a more practical example of processing at the step S43 and steps subsequent thereto of the flowchart shown in FIG. 16.

FIG. 19 is a flowchart for explaining operation of another more practical example of this invention.

FIG. 20 is a block diagram showing an example of the configuration of the main part of curve generating means for generating curve by the more practical example of path search method.

FIG. 21 is a flowchart showing basic processing procedure of the path search method.

FIG. 22 is a view for explaining processing for carrying out path search on the basis of the path search method.

FIG. 23 is a view for explaining internal configuration of path search processing optimization means.

FIG. 24 is a flowchart for explaining processing procedure in the path search processing optimization means.

FIG. 25 is a view for explaining processing relating to passing cost calculation parameter of the path search processing optimization means.

FIG. 26 is a flowchart for explaining processing procedure in the path search means.

FIG. 27 is a view for explaining, in detail, processing relating to passing cost calculation parameter utilizing selective gradient detection.

FIG. 28 is a flowchart for explaining processing procedure in passing cost optimization means.

FIG. 29A is a view showing one example of passing cost map of path search and FIG. 29B is a view showing process where minimum cost path calculation means determines path when passing cost map is obtained.

FIG. 30 is a view showing one example of the shortest path search algorithm using dynamic programming.

FIG. 31 is a view for explaining in detail processing relating to calculation range optimization of path search processing optimization means.

FIG. 32 is a flowchart for explaining processing procedure in calculation range optimization means.

FIG. 33 is a block diagram showing an example of the configuration of point train generating means.

FIG. 34 is a flowchart for explaining processing procedure in the point train generating means.

FIG. 35 is a block diagram showing the configuration of a more practical example of optimum color projection axis calculating unit for determining color

projection axis.

FIG. 36 is a view for explaining the operation principle of a more practical example of the optimum color projection axis calculating unit.

FIGS. 37A and 37B are views for explaining the operation principle of another more practical example of the optimum color projection axis calculating unit.

## Best Mode for Carrying Out the Invention

Preferred embodiments of this invention will now be described in detail with reference to the attached drawings.

A curve generating apparatus 1 to which this invention is applied is caused to be of configuration as shown in FIG. 4, for example. This curve generating apparatus 1 is adapted so that a program memory 3, a data memory 4, a frame memory 5, an operation input unit 6, and an external storage (memory) unit 7 are connected to an arithmetic processing unit 2 through a bus 8.

In the program memory 3, there is recorded program for executing a curve generating method according to this invention. Namely, the program memory 3 records therein, as software program, the curve generating method comprising a correspondence point detection step of determining, by using curve to be generated or processed of the first frame, correspondence points at second frame corresponding to reference correspondence points set on the curve to be generated of the first frame, and a curve generation step of generating curve of the second frame passing through

correspondence points detected by the correspondence point detection step.

The operation input unit 6 is comprised of, e.g., keyboard and/or mouse, etc. and serves to generate an operation input signal as the result of the fact that it is operated by user. This operation input unit 6 outputs the operation input signal to the arithmetic processing unit 2.

The arithmetic processing unit 2 generates control signals with respect to the above-described respective units in accordance with operation input signals from the operation input unit 6. Further, the arithmetic processing unit 2 outputs control signals thus generated to respective units to thereby carry out processing corresponding to the operation input signals. Namely, the arithmetic processing unit 2 conducts such a control to read out in sequence the software programs from the program memory 3 to execute them to generate contour curve indicating contours of curves to be generated included in respective frames by using picture data indicating moving picture stored in the external recording unit 7.

Picture image data processed by the software\* program from the program memory 3 is stored in the external storage unit 7 as described above. The external storage unit 7 comprises recording medium, e.g., optical disc, etc. and outputs, in accordance with control signal from the arithmetic processing unit 2, picture data indicating moving picture recorded on the recording medium to the arithmetic processing unit 2, the data memory 4 and the frame memory 5. In addition, the external storage (memory) unit 7 records, onto the recording medium, other picture

data delivered from the external.

As shown in FIG. 5, for example, picture image data stored in the external storage unit 7 consists of plural frames Fr1, Fr2, Fr3, Fr4, Fr5, Fr6 and Fr7 to constitute moving picture. In this example, frame Fr1 is start frame and end frame with respect to the frame Fr1 is frame Fr3. Namely, this curve generating apparatus 1 executes the program relating to the curve generating method of this invention to thereby generate intermediate curve with respect to frame Fr2 which is intermediate frame by using first contour curve of data to be generated included in the frame Fr1 and second contour curve of data to be generated included in the frame Fr3.

In the data memory 4 of FIG. 4, there is stored contour curve indicating contour of intermediate frame generated by the above-described arithmetic processing unit 2 for executing the program, etc. In addition, into this data memory 4, data in the middle of arithmetic processing by the arithmetic processing unit 2 is also stored.

Picture image data corresponding to one frame from the data memory 4 or the external storage (memory) unit 7, etc. is inputted to the frame memory 5 in accordance with control signal of the arithmetic processing unit 2. Picture image data which has been read out by control signal from, e.g., arithmetic processing unit 2 or contour curve indicating intermediate frame generated by the program, etc. is inputted to the frame memory 5. Further, this frame memory 5 is connected to a display unit 9 for displaying picture image and/or processing content, etc. to user, and outputs picture image data, etc. inputted in accordance with control signal to the display unit 9 to

thereby allow the display unit 9 to display thereon picture image that the above-mentioned picture image data indicates.

The program to which the curve generating method of this invention is applied is operated by the processing procedure shown in FIG. 6.

At step S101, user gives, as input, two curves at the time of start and at the time of end and reference correspondence points with respect to respective curves. In this case, two curves are respectively referred to as curves A and B. It is required that the numbers of reference correspondence points are the same with respect to the curves A and B. Then, at step S102, pursuit operation of reference correspondence points is carried out with respect to picture images successive in the time axis direction. As a result, positions of reference correspondence points at respective intermediate stages can be determined. The detail thereof will be described later.

Then, at step S103, interpolation of shape is carried out. In order to carry out shape interpolation, such an approach is employed to carry out interpolation calculation of coordinates of point trains on two curves that user designates at the step S101 to thereby determine coordinates of points of intermediate shapes. Although there may be employed any transformation (conversion) to provide intermediate shape of two shapes, there is employed in this example the technology disclosed in the Japanese Patent Application No. 251492/1998 by the applicant of this application. The detail thereof will be described later.

Then, at step S104, the interpolated shape determined at the step S103 is

deformed in correspondence with reference correspondence points determined by pursuit operation at the step S102.

Accordingly, by executing the program, it can be equivalently said that the arithmetic processing unit 2 comprises a correspondence point detecting section for determining, by using curve to be generated or processed of the first frame, correspondence points at intermediate frame corresponding to reference correspondence point set on the curve to be generated of frame at the time of start, and a curve generating section for generating curve of intermediate frame passing through correspondence point detected by the correspondence point detecting section.

Particularly, the above-mentioned correspondence point detecting section carries out picture image pursuit operation at the step S102 to detect where reference correspondence point on curve to be generated or processed of frame at the time of start is positioned at the intermediate frame.

In addition, the curve generating section generates curve passing through correspondence points detected by the correspondence point detecting section through the steps S103 and S104. In more practical sense, when frame at the time of end is assumed to be the third frame, interpolated curve is determined by linear interpolation from curve to be generated or processed of the first frame and curve to be generated or processed of the third frame to deform the interpolated curve thus obtained into curve passing through correspondence points detected at the correspondence point detecting section.

Operations at the respective steps of FIG. 6, i.e., processing that the arithmetic processing unit 2 carries out will now be described in detail.

At step S102, there is carried out an operation to pursue position of reference correspondence points in picture images successive on the time axis. As a pursuit method of picture image, there may be employed any methods of pursuing points on the picture image. Here, explanation will be given with reference to FIG. 7 in connection with a method of carrying out pursuit by using absolute value sum of differences of picture images, which is known as SSD as an example. When picture image around reference correspondence point 10 at pursuit source frame  $F_0$  shown in FIG. 7 is assumed as pursuit source image 20, pursuit destination images 40 are prepared with respect to all coordinates within the region of search range 30 designated at frame  $F_1$  which is pursuing at present shown in FIG. 7 to determine by calculation analogousness between two images, i.e., pursuit source image  $20_1$ , and pursuit destination image  $40_1$ . As a method of determining analogousness between images, there is used a method of determining absolute value sums of differences of respective pixel values within image region with respect to two images  $20_1$  and  $40_1$  to allow them to be evaluation value to allow coordinates having the lowest evaluation value within the region to be pursuit result.

Explanation will now be described in connection with interpolation calculation of shape at step S103 will be described below. In FIG. 8, there are shown two curves where the numbers of segments are not in correspondence with each other. An

example for generating intermediate curve when change from first contour curve A to second contour curve B takes place will now be described. In this case, when end point, control point and line segment of third-order Bezier curve are assumed to be one segment, the first contour curve A consists of five segments  $S_m$  and the second contour curve B consists of three segments  $S_m$ . In addition, when intermediate curve in the case where change from first contour curve A to second contour curve B takes place as shown in FIG. 9, for example, is generated (indicated as intermediate curve group  $Z_c$  to be generated in FIG. 9), procedure shown in the flowchart of FIG. 10 is executed.

When the intermediate curve is generated, correspondence points indicating corresponding positions of the first contour curve A and the second contour curve B are designated by operation of keyboard, etc. by user. Thus, at step S1, correspondence points are set at the first contour curve A and the second contour curve B in accordance with the operation to the effect that the above-described correspondence points are designated to develop the first contour curve A and the second contour curve B into one straight line as shown in FIG. 11 to determine respective entire lengths of the first and second contour curves A and B which are closed curve to allow the respective entire lengths of the first and second contour curves A and B to be length A and length B, respectively.

Then, at step S2, sampling intervals of the entire length A of the first contour curve A and the entire length B of the second contour curve B are determined.

Namely, such an approach is employed to compare magnitudes (sizes) of the length A and the length B to divide one longer in length by constant of the sampling interval to determine the number of points within the section (step S11 of the flowchart shown in FIG. 12). In this case, constant of the sampling interval is sampling interval where there can be obtained the number of points necessary for processing for reconstructing curve which will be described later at processing for generating such intermediate shape. Then, such an approach is employed to divide smaller one of magnitudes of length A and length B by the number of sampling points determined at the step S11 to obtain sampling interval (step S12 of FIG. 12). For this reason, sampling operations are carried out by sampling intervals less than the maximum sampling interval  $L_{MAX}$  with respect to both curves at all times.

Returning to FIG. 10, at step S3, resampling processing of curve A and curve B are carried out at sampling intervals determined at the step S2 to prepare point trains. Such state is shown in FIG. 13. FIG. 13 shows the state where resampling processing are carried out with respect to the first contour curve A and the second contour curve B by using sampling intervals obtained at step S11. In this case, points on segment of one Bezier curve can be represented as a function of time  $t$  as described below.

$$Q(t) = ((1-t)^3)M + 3t(1-t)^2N + 3(t^2)(1-t)O + (t^3)P \quad (0 \leq t \leq 1)$$

In the above formula, M, N, O, P are coordinates indicating points on the two-dimensional plane, wherein M, P are end points of line segment, and N, O are control

points. Further, in order to represent, by  $t$ , points on the Bezier curve constituted by connecting plural segments, definition of the Bezier curve is extended to allow the integral part of  $t$  to be segment No. and to allow the decimal part of  $t$  to be time within segment. Namely, in the case of  $t=3.45$ , this indicates coordinate on the curve of the third segment and at time of 0.45. Thus, points on the Bezier curve constituted by plural segments are represented by  $t$ .

Moreover, detailed flowchart of resampling processing carried out at the step S3 of FIG. 10 is shown in FIG. 14. When resampling processing is carried out, times at correspondence points of the first contour curve A and the second contour curve B corresponding to correspondence point O shown in FIG. 13 are set as  $T_a$  and  $T_b$ . At the subsequent step S22, coordinates of points on the first contour curve A and the second contour curve B at times  $T_a$ ,  $T_b$  are determined. Respective points determined here result in sampling points at the first contour curve A and the second contour curve B. At the subsequent step S23, sampling interval determined at the above-described step S2 of FIG. 10 is added to times  $T_a$ ,  $T_b$ . At the subsequent step S24, there is judged whether or not times  $T_a$ ,  $T_b$  reach terminating ends so that correspondence points return to correspondence points at the time of start of resampling processing. Further, when it is judged that correspondence point returns to correspondence point at the time of start, the processing is completed. On the other hand, when it is judged that correspondence point does not return to the correspondence point, the processing returns to step S22 to repeat processing of the above-described steps S22 to S24 to set,

for a second time, sampling points at the first contour curve A and the second contour curve B to generate point train consisting of sampling points. Namely, in the resampling processing of the step S3 of FIG. 10, there are generated point train corresponding to the first contour curve A and point trains corresponding to the second contour curve B which consist of sampling points finer than those at the above-described sampling processing.

Further, returning to FIG. 10, at step S4, such an approach is employed to carry out interpolation calculation of coordinates of point trains on two curves prepared at the previously mentioned step S3 to thereby determine point train of intermediate shape. In more detail, processing shown in flowchart of FIG. 15 is carried out to thereby generate intermediate curve indicating intermediate shape when there takes place change from the contour shape that the first contour curve A indicates to contour shape that the second contour curve B indicates. In accordance with the flowchart of FIG. 15, first, at step S31, point train corresponding to the first contour curve A and point train corresponding to the second contour curve B which are determined by resampling processing of the step S3 of FIG. 10 are inputted from the data memory 4. Further, there are designated sampling points at positions corresponding to correspondence points on point train corresponding to the first contour curve A and point train corresponding to the second contour curve B from the correspondence points. At the subsequent step S32, when time at which interpolation of two curves is carried out is assumed to be T with respect to point train consisting of sampling

points, coordinate of point on the first contour curve A is assumed to be a, and coordinate of point on the second contour curve B corresponding to the coordinate a is assumed to be b, coordinate C of the point at intermediate curve indicating the intermediate shape to be determined is expressed by the following formula (2).

$$C = T \cdot a + (1-T) \cdot B \quad (2)$$

Namely, by applying the above-mentioned formula (2) to point trains corresponding to first and second contour curves, coordinate of sampling points constituting intermediate curve is determined from sampling points corresponding to the first contour curve A and sampling points corresponding to the second contour curve B corresponding to sampling points corresponding to the first contour curve A. At the subsequent step S33, processing for designating next sampling points of the sampling points where the formula (2) is applied at the above-described step S32 is carried out with respect to point train corresponding the first contour curve A and point train corresponding to the second contour curve B. At the subsequent step S34, the arithmetic processing unit 2 judges whether or not correspondence point returns to the correspondence point where generation processing of intermediate curve is started at the above-described step S31 as the result of the fact that next sampling point is designated at the above-described step S33. Further, when it is judged that correspondence point returns to the corresponding point, the processing proceeds to step S35. On the other hand, when it is judged that correspondence points does not return to the correspondence point, the processing which has been explained at the step

S32 is carried out with respect to sampling points designated at the step S33. Namely, the processing which has been explained at the step S32 is carried out with respect to all of sampling points set at the above-described sampling processing of the step S3 to thereby determine coordinate of points at the intermediate curve in accordance with the above-mentioned formula (2). At step S35, by using sampling points determined at the above-described step S3 and coordinate C of point at the intermediate curve determined at the step S32, the technology shown in the Japanese Patent Application Laid Open No. 164436/1998 publication or “An Algorithm for Automatically Fitting Digitized Curves (pp. 612-626) in the “Graphics Gems” (Andrew S. Glassner) is applied to thereby transform (convert) point train consisting of sampling points into Bezier curve. Thus, curve is reconstructed from point train consisting of sampling points corresponding to first contour curve A and point train consisting of sampling points corresponding to the second contour curve B to generate intermediate curve indicating intermediate shape when change from first contour curve A to second contour curve B takes place as shown in FIG. 9.

The curve generating apparatus 1 for carrying out such an intermediate curve generation processing is adapted so that when, as shown in FIG. 8, intermediate curve when there takes place change from the first contour curve A to the second contour curve B is generated, even if the numbers of segments of the first contour curve A and the second contour curve B are different from each other, the first and second contour curves are caused to undergo sampling to set the same number of sampling points with

respect to the first contour curve A and the second contour curve B to re-construct curve. Accordingly, it is possible to generate intermediate curve group Zc as shown in FIG. 9 with high quality and simply.

Then, at step S104 of FIG. 6, interpolated shape determined at step S103 is deformed in correspondence with reference correspondence points determined at the step S102. Explanation will be given with reference to FIGS. 16, 17 and 18 with respect to such an operation. FIG. 16 is the detail of deformation processing of the step S104, FIG. 17 is a view used for explanation from the start START up to the step S42 thereof, and FIG. 18 is a view used for explanation from the step S43 up to the end END.

First, at step S41 of FIG. 16, start point 115 and end point 116 are caused to correspond to each other with respect to reference correspondence points 110 indicated at START of FIG. 17 determined by image pursuit processing of the step S102 of FIG. 6 and reference correspondence points 100 indicated at START of FIG. 17 determined at the intermediate shape preparation processing of the step S103. It is now assumed that coordinates of start points at the step S103 are A (ex1, ey1) and B(ex2, ey2) and coordinates of end points at the step S102 are C(sx1, sy1) and D(sx2, sy2). At the step S42, such a coordinate transformation (conversion) to convert line segment AB into line segment CD is determined. Such a transformation can be represented by combination of parallel displacement and rotation, and operation of scaling. Such a transformation is called affine transformation 120.

The transform formular of affine transformation is as follows.

With respect to the method of transforming point (x, y) into point (x', y') by the affine transformation, the following relational expression is assumed to hold.

$$[x'] = sc * [\cos\theta - \sin\theta][x-ex1] + [sx1]$$

$$[y'] = sc * [\sin\theta - \cos\theta][y-ey1] + [sy1]$$

In the above formula,  $sc = L1/L2$

$$L1 = \sqrt{((sx2-sx1)^2 + (sy2-sy1)^2)}$$

$$L2 = \sqrt{((ex2-ex1)^2 + (ey2-ey1)^2)}$$

$$\theta = \theta2 - \theta1$$

$$\theta1 = \tan^{-1}((sy2-sy1)/L1, (sx2-sx1)/L1)$$

$$\theta2 = \tan^{-1}((ey2-ey1)/L1, (ex2-ex1)/L2)$$

Then, at the step S43, affine transformation determined at the step S42 is calculated with respect to point train constituting intermediate shape determined at the step S102 of FIG. 6. As a result, as shown in FIG. 18, there is prepared shape which holds feature of intermediate shape determined at the step S103 and passing through end point determined at the step 102. Then, at step S44, by using the method of transforming (converting) point train determined at step S43 into the previously described Bezier curve, transformation into curve is carried out. By carrying out such a processing with respect to all sections of shape, it becomes possible to transform shape prepared at the intermediate shape preparation processing of the step S103 into shape passing through reference correspondence points prepared at the step S102.

As described above, in accordance with this invention, in preparing intermediate shape of two curves, it becomes possible to prepare intermediate shape passing through designated reference correspondence points. In addition, it is possible to set reference correspondence point at precise position by image pursuit processing. As a result, it has become possible to prepare, with high precision, intermediate shape determined at picture image designated on the time axis. Thus, positional shift between shape by linear interpolation and actually determined shape which was the problem of the prior art can be solved.

Another more practical example of this invention will now be described. In FIG. 19, there is shown the example in which the step S103 is omitted among the condition of the first embodiment shown in FIG. 6 and the portion of the step S104 is realized by another method as step S105.

Edge information of picture image is used as substitutive means for preparing intermediate shape to carry out processing for automatically generating shape passing through the reference correspondence point and along the edge. In more practical sense, as a method of detecting optimum path passing through the designated point, there is used the technology of path search method disclosed in the Japanese Patent Application No. 204862/1997 by the applicant of this application.

Explanation will be first given in connection with curve generating means which generates curve by the path search method disclosed in the Japanese Patent Application No. 204862/1997.

FIG. 20 is a block diagram showing curve generating means. The curve generating means is composed of respective processing means composed of two point selector means 151, path search processing optimization means 152, path search means 153 and curve approximate means 154, and respective data stores (storages) 16, 17, 23, 18 for point train, picture image, path and curve.

The two point selector means 151 selects successive two points  $P_1, P_2$  from the point train data storage means 16 to output them. The path search processing optimization means 152 calculates path search parameter  $P_{r1}$  for optimizing the path search method from the selected two points  $P_1, P_2$  and picture image data  $D_V$  from the picture data storage means 17 to send it to the path search means 153.

The path search means 153 determines path search processing method on the basis of the path search parameter  $P_{r1}$  that the path search processing optimization means 152 has calculated to calculate path data connecting the selected two points  $P_1, P_2$  and passing on the contour within picture image to hold it by the path data storage means 23.

In this case, path data is list of pixel coordinates indicating eight vicinity graphics connecting the above-mentioned two points. As indicated by broken lines in FIG. 20, the path search means 153 sends control information  $J_{CN}$  to the two point selector means 151 to select the next two points. Accordingly, path searches are carried out with respect to portions between respective points of the point train storage means 16 so that all the search data are accumulated (stored) into the path data storage

means 23.

When the two point selector means 151 has selected until the last of the point train to fail to output new two points, it sends control information  $I_{CN}$  to the curve approximate means 154 as indicated by broken lines in FIG. 20 to hasten the operation of the curve approximate means 154. The curve approximate means 154 carries out curve approximation of path stored in the path data storage means 23 to prepare curve data indicating contour shape to hold it by the curve data storage means 18.

Explanation will now be given with reference to FIGS. 21 and 20 in connection with path search method that the curve generating means executes.

FIG. 21 is a flowchart showing fundamental processing procedure of the path search method according to this invention. First, at step S1, the two point selector means 151 selects successive two points from the point train data storage means 16 to output them.

Then, at step S2, optimization of path search parameter is carried out. Path search parameter  $P_{rl}$  is calculated by the path search processing optimization means 152 on the basis of the two points  $P_1, P_2$  selected by the two point selector means 151 and picture data  $D_V$ .

Then, at step S3, path search is carried out. The path search means 153 determines the path search method on the basis of path search parameter obtained at the second step S2 to extract contour connecting the above-mentioned two points in the form of 8 vicinity path.

Further, at step S4, there is carried out judgment as to whether or not path searches between all relaying (repeating) points have been completed. As a result, if such path searches have not yet been completed, the processing returns to step S1 to select two points in which one point is shifted from the two points selected at last time to repeat steps S2, S3. On the other hand, when it is judged at step S4 that path searches between all relaying points have been completed, the processing proceeds to step S5.

At the step S5, contour curve which approximates 8 vicinity path is generated to complete the processing. The curve approximate means 154 carries out curve approximation of path data stored in the path data storage means 23 to prepare curve data indicating contour shape.

In this case, the curve approximate means 154 can be realized by the technology in which the applicant of this application has disclosed "Curve Generating Apparatus and Curve Generating Method" in the Japanese Patent Application No. 303687/1996 publication. This technology is a method of obtaining curve which approximates coordinate list and is one of the so-called curve approximation methods. Namely, this method is method of approximating order of input data while dividing it within the sufficiently approximatable range so that this method is robust to noise and has good efficiency as compared to the conventional curve approximations.

However, the above-mentioned curve approximation means 154 may be methods of curve-approximating a series of coordinate lists, and may be realized by

a method of generating B-spline curve generally used, etc.

It is to be noted that general curve approximation/interpolation methods are described in detail in articles such as "Numerical Calculation Handbook" (Yutaka Ohno, Kazuo Isoda, Ohm Company, 1990), "Shape Processing Engineering [I][II]" by Computer Display" (Fujio Yamaguchi, Nikkan Kogyo Shinbun Sha, 1982, "Computer Graphics Principles and Practice" (Foly, vanDam, Feiner, and Hughes, Addison Wesley Company, 1990), etc.

The path search processing optimization means 152 and the path search means 153 will now be described in more detail.

FIG. 22 is a block diagram in which the portion for carrying out path search is extracted of the curve generating means. The feature of the curve generating means for carrying out this path search resides in that path search processing optimization means 152 is provided to thereby carry out path search processing optimized with respect to inputted two points. In this example, the path search processing optimization means 152 is adapted to output two kinds of path search parameters  $P_{r2}$  and  $P_{r3}$  which will be described later.

FIG. 23 shows the internal configuration of the path search processing optimization means 152. The path search processing optimization means 152 is composed of passing cost calculation range determining means 156 and passing cost calculation optimization means 157. The passing cost calculation range determining means 156 inputs selected two points  $P_1, P_2$  to output calculation range parameter  $P_{r3}$ .

Further, the passing cost calculation optimization means 157 outputs passing cost calculation parameter  $P_{r2}$  from the selected two points  $P_1, P_2$  and picture data  $D_v$ . In addition, these two kinds of path search parameters  $P_{r2}$  and  $P_{r3}$  are inputted to the path search means 153 and are used for determining the path search method.

FIG. 24 is a flowchart showing processing procedure at the path search processing optimization means 152.

First, at step S11, optimization of passing cost calculation parameter is carried out. Namely, the passing cost calculation optimization means 157 calculates passing cost calculation parameter  $P_{r2}$  from the selected two points (point  $P_1$  and point  $P_2$ ) and picture image data  $D_v$ . Then, at step S12, optimization of the passing cost calculation range parameter is carried out to complete the processing. Namely, the passing cost calculation range determining means 156 inputs selected two points  $P_1, P_2$  to calculate passing cost calculation range parameter  $P_{r3}$ .

FIG. 25 is a block diagram showing, in more detail, the portion for carrying out processing relating to passing cost calculation parameter  $P_{r2}$  in FIG. 23.

The passing cost calculation optimization means 157 is caused to be of configuration comprising gradient parameter determining means 158.

Moreover, the path search means 153 is caused to be of configuration comprising passing cost calculation means 159, minimum cost path calculating means 161, and passing cost map storage means 160 for storing data called passage cost map which will be described later.

The gradient parameter determining means 158 inputs picture data  $D_v$  and two points  $P_1$ ,  $P_2$  to calculate gradient parameter  $P_{r4}$  (a sort of passing cost calculation parameters) optimum for extracting contour between the two points to output it to the passing cost calculating means 159 of the path search means 153.

The passing cost calculating means 159 inputs picture data  $D_v$ , the point  $P_1$ , the gradient parameter  $P_{r4}$ , and calculation range parameter  $P_{r3}$  that the passing cost calculation range determining means 156 shown in FIG. 23 outputs to calculate passing cost map to output it to the passing cost map storage means 160.

The minimum cost path calculating means 161 inputs passing cost map from the passing cost map storage means and the point  $P_2$  to calculate path data  $D_p$  connecting the points  $P_1$  and  $P_2$  so as to trace the contour therebetween.

FIG. 26 is a flowchart showing processing procedure at the path search means 153.

First, at step S21, the passing cost calculating means 159 calculates passing cost map. Then, at step S22, the minimum cost path calculating means 161 calculates the minimum cost path. The detail of this operation will be described later.

FIG. 27 shows, in more detail, the configuration of the portion for carrying out processing relating to the above-described passing cost calculation parameter.

The passing cost calculation parameter  $P_{r2}$  is two kinds of parameters necessary in calculating gradient of picture image. The first parameter is normal vector  $V_1$  indicating direction perpendicular to advancing direction of contour, and the second

parameter is pixel value color change vector  $V_0$  indicating change of pixel value when observed in a direction traversing the contour.

Moreover, the path search means 153 carries out a processing to extract, by utilizing the fact that object contour has high gradient strength, such a path on the picture image to pass as close as possible the portion having higher gradient strength.

In order to carry out processing as described above, the pass cost calculating means 159 is composed of gradient calculating means 164, passing cost map calculating means 165 and gradient data storage means 21.

The gradient calculating means 164 calculates gradient of picture image. The passing cost map calculating means 165 calculates passing cost map such that when path is passed through the portion where gradient strength is higher, cost is reduced to more degree on the basis of the gradient thus obtained. Position of the point  $P_1$  is inputted to the passing cost map calculating means 165 and starting point of the passing cost map is set at the point  $P_1$ .

In this example, the gradient calculating means 164 selectively detects only gradient component of necessary contour by using the technology in which the applicant of this application has disclosed in "Edge Detection Method and Edge Detection Apparatus" in the Japanese Patent Application No. 134420/1995 publication. By this gradient calculating means 164, gradient is calculated so as to selectively extract gradient of contour extending in a manner connecting inputted two points.

Explanation will now be given in detail in connection with calculation process of the above-described two kinds of path search parameters.

First, calculation of passing cost calculation parameter  $P_{r2}$  and the process where such parameter is utilized will be described. FIG. 28 is a flowchart showing processing procedure at the gradient parameter determining means 158. At step S31, normal vector calculating means 162 calculates normal vector  $V_1$  perpendicular to the direction connecting inputted points  $P_1$  and  $P_2$  to output it. At step S32, pixel value change vector calculating means 163 calculates change of pixel value of picture image when observed in a direction perpendicular to the direction connecting two points, e.g., color change direction in the neighbouring region of the points  $P_1$  and  $P_2$  on the picture image to output it as color change vector  $V_0$ .

In this example, the passing cost map is information in which, in each pixel, direction admitted to that pixel position at minimum passing cost is recorded.

FIG. 29 shows an example of simple passing cost map.

The passing cost map is prepared with respect to one range within picture image designated by the passing cost calculation range parameter  $P_{r3}$ . In this example, there is shown an example where such map is prepared in a certain small quadrilateral region.

In FIG. 29A, directions admitted to that pixel position at the minimum passing cost in the respective pixels are indicated by arrow. This direction is calculated so that only one direction is determined in each pixel. Value labeled at each pixel is

accumulated value of passing cost when admitted in accordance with the minimum passing cost direction. This accumulated value is determined by allowing point POINT 1 serving as starting point of path search as accumulated value 0.

FIG. 29B shows process where minimum path calcualting means 161 determines path when passing cost map is obtained as shown in FIG. 29A.

The minimum cost calculating means 161 inputs passing cost map and the point POINT 2 to trace, in an opposite direction, minimum passing cost direction of the passing cost map from the point POINT 2 to thereby determine path of the minimum cost ranging from the point POINT 1 to the point POINT 2. For example, in the case where the point POINT 2 is located at position shown in FIG. 29 (accumulated cost is 22), the arrows are traced from the point POINT 2 (written in a direction opposite to that in FIG. 29A) to determine path until the point POINT 1 as indicated by slanting lines.

Explanation will now be given in connection with means for calculating passing cost map as described above at a high speed. Calculation of passing cost map is generally known as a sort of optimization problem, and a method of calculating such a cost map by using dynamic programming, etc. is well known. Also in the previously described article "Intelligent Scissors for Image Composition", a method using dynamic programming is described.

FIG. 30 shows an example of description relating to shortest path search algorithm using dynamic programming. It is to be noted that, in this description, signs,

etc.. are partially changed from the program described in the above-mentioned article "Intelligent Scissors for Image Composition".

Calculation of calculation range parameter and process where such parameter is utilized will now be described.

FIG. 31 is a block diagram showing, in more detail, the portion for carrying out processing relating to calculation range parameter in FIG. 23.

The passing cost calculation range determining means 156 is caused to be of configuration comprising distance calculating means 167, calculation range width calculating means 168, calculation range length calculating means 169, and calculation range calculating means 170.

The distance calculating means 167 inputs points  $P_1, P_2$  to calculate distance  $L$  between the two points and direction  $G$  connecting the two points. The calculation range length calculating means 169 inputs the distance  $L$  between the two points obtained to calculate calculation range length  $SL$ . The calculation range width calculating means 168 inputs distance  $L$  between the two points obtained to calculate calculation range width  $SW$ . The calculation range calculating means 170 calculates calculation range parameter  $P_{13}$  to determine shape of the calculation range on the basis of the above-mentioned calculation range length  $SL$ , calculation range width  $SW$  and direction  $G$  connecting two points that the distance calculating means 167 has outputted to input it to the passing cost calculation means 159 of the path search means 153. The passing cost calculation means 159 calculates passing cost map

within the range indicated by the calculation range parameter  $P_{13}$ .

FIG. 32 is a flowchart showing processing procedure at the passing cost calculation range determining means 156 of FIG. 31.

First, at step S41, the distance calculating means 167 inputs points  $P_1$  and  $P_2$  to calculate distance  $L$  between these two points and direction  $G$  connecting two points.

Then, at step S42, the distance  $L$  between the two points is inputted. Thus, calculation range width  $SW$  is calculated. In this case, the calculation range width calculating means 168 has therein rule of magnitude (size) of calculation range width  $SW$  with respect to magnitude (size) of distance  $L$  between two points in the form such as calculation formula or reference table, etc. to determine calculation range width  $SW$  in accordance with that rule. For example, the problem in which even if operator attempts to set relaying (repeating) points in detail at short intervals in order to obtain a desired contour, searched path is meandered between relaying points so that shape differs from desired shape of contour can be solved by employing a rule such that the rule for determining calculation range width  $SW$  changes to a rule such that according as distance between two points becomes smaller, width becomes smaller.

At this time, calculation range width  $SW$  between relaying (repeating) points set in detail at short intervals is set so that it becomes very narrow, and path search is carried out so that relaying (repeating) points are connected by substantially straight line. Thus, contour shape that operator desires is obtained.

Then, at step S43, the calculation range length calculating means 169 calculates

calculation range length SL from distance L between two points. In this case, the calculation range length SL is determined so that it is larger than the distance L between two points by margin length determined in advance.

Finally, at step S44, the calculation range calculating means 170 calculates calculation range parameter  $P_{i3}$  from the calculation range width SW, the calculation range length SL and direction G connecting two points. In this case, the calculation range is such a rectangle to surround inputted two points  $P_1$ ,  $P_2$  and inclined in the direction connecting two points, and the calculation range parameter  $P_{i3}$  indicates positions of four corners of that rectangle.

The point train generating means 12 will now be described.

The point train generating means 12 inputs curve C to output point train reproducing that shape and reconstructed curve reconstructed by that point train. The point train and the reconstructed curve which have been generated are used for curve editing work which will be carried out later by the configuration of the first embodiment.

FIG. 33 is a block diagram showing an example of the configuration of the point train generating means 12.

This point train generating means 12 is caused to be of configuration comprising initial point train generating means 171, curve reconstructing means 172, difference detecting means 173, point train editing means 14, picture image data storage means 17, point train data storage means 16, and reconstructed curve data

storage means 19.

The initial point train generating means 171 inputs input curve C and picture data D<sub>v</sub> to generate initial point train. The point train is stored in the point train data storage means 16. The curve reconstructing means 172 inputs point train and picture image data D<sub>v</sub> to generate such a curve to pass the point train and to pass on the contour of the picture image.

The difference detecting means 173 inputs input curve C and re-constructed curve C' to output difference between both shapes as difference dif. The point train editing means 14 operates point train data in the point train data storage means 16 on the basis of difference dif that the difference detecting means 173 has outputted.

FIG. 34 is a flowchart showing processing procedure in the point train generating means 12.

First, at step S51, the initial point train generating means 171 carries out extraction of feature points of input curve C to store the extracted feature points into the point train data storage means 16 as initial point train.

For the above-mentioned feature point extraction on the curve, there may be used feature point extraction method shown in "Motion Vector Estimation Method" described in the Japanese Patent Application Laid Open No. 335270/1996 publication. In accordance with this method, such an approach is employed to calculate very small section bending angles at respective points from the initial end to the terminating end of curve to allow its sum total to be accumulated bending angle, whereby when the

accumulated bending angle is greater than a threshold value determined in advance, the point which takes the maximum very small section bending angle is caused to be feature point. Further, similar feature point extraction processing is recursively carried out with respect to curve divided by feature points.

Then, at step S52, the curve re-constructing means 172 calculates re-constructed curve by processing similar to the processing in the previously described path search apparatus according to this invention from the point train.

Then, at step S53, the difference detecting means 173 calculates difference dif between input curve and re-constructed curve. In accordance with such difference detection processing, such an approach is employed to take difference detection points at suitable intervals on the re-constructed curve to measure distance up to input curve from that difference detection point to allow it to be difference value dif.

Then, at step S54, the difference detecting means 173 examines whether or not there exist difference value dif greater than threshold value set in advance. If there does not exist difference value greater than the threshold value, the processing of the point train generating means 12 is completed. Thus, data in the point train data storage means 16 and re-constructed curve data storage means 19 at that time point serve as output. On the other hand, if there exists difference value greater than the threshold value, the processing proceeds to step S55.

At the step S55, the point train editing means 14 edits point train data on the basis of difference dif thus obtained. At respective difference detection points in

which it is judged that the difference value dif is greater than threshold value, new relaying (repeating) point is placed at point on the input curve nearest from that difference detection point to store point train data into the point train data storage means 16.

After completion of the step S55, the processing returns to the step S52. Thus, at step S54, processing is repeated until difference between input curve C and re-constructed curve C' becomes smaller than threshold value.

While, in the above-mentioned processing, the number of points constituting initial point train is set to lesser value at first to suitably supplement initial points at the shortage portions, there may be employed a method in which the number of points constituting initial point train is set to larger value to delete unnecessary points. In that case, such an approach may be employed to generate initial point train to such a degree that input curve can be sufficiently polygon-approximated by the initial point train generating means 171 to select and delete relaying (repeating) points in which difference value therearound is sufficiently smaller than threshold value by the difference detecting means 173 after re-construction of the curve.

It is to be noted that while, in the processing procedure shown in FIG. 34, since re-construction can be completed by lesser number of points, there results the merit that curve editing thereafter is easy, processing procedure which will be described later has the merit that because relaying (repeating) point interval for carrying out path search can be small, processing time can be shortened.

Moreover, point train obtained by the above-mentioned method is transformed (converted) into curve by using curve generating means. Namely, by using edge information of picture image in preparing intermediate shape passing through portions between respective correspondence points by using the above-mentioned method, it has become possible to prepare contour having high precision along the shape represented in the picture image.

Further, in the method shown in FIG. 19, such an approach may be employed to determine edge of picture image by using another algorithm at step S105 to determine intermediate shape along the edge of that picture image.

Namely, at step S102, a set of correspondence points determined by picture image pursuit and the picture image are used to determine color projection axis which maximizes contrast around the edge to form edge of picture image by using such color projection axis to determine intermediate shape along this edge.

The configuration of optimum color projection axis calculating unit 32 which inputs the set of correspondence points as representative points Q1 and Q2 to determine the color projection axis  $P_{j0}$  is shown in FIG. 35.

The optimum color projection axis calculating unit 32 is composed of a representative point vicinity (neighbouring) color projection axis calculating section 41a and a representative point vicinity (neighbouring) optimum color projection axis calculating section 41b for calculating vicinity (neighbouring) optimum color projection axes  $P_{j1}$  and  $P_{j2}$  within the region in the vicinity of representative points Q1

and Q2, and a color projection axis synthesis section 42 for synthesizing color projection axis  $P_{j0}$  by using the color projection axis  $P_{j1}$  and the color projection axis  $P_{j2}$  from the above-mentioned two calculating sections 41a, 41b.

At the representative point vicinity (neighbouring) optimum color projection axis calculating sections 41a and 41b, there are determined vicinity (neighbouring) optimum color projection axes  $P_{j1}$  and  $P_{j2}$  which maximize contrast around the edge included within neighboring regions of representative points Q1 and Q2. It is now assumed that, as shown in FIG. 36, representative points Q1 and Q2 are determined within the regions color-separated by black B, white W, green G, yellow Y, red R and blue B. At this time, the representative point vicinity (neighbouring) color projection axis calculating section 41a determines, by calculation, color projection axis  $P_{j1}$  in which the contrast is maximum of edge included within the neighboring region A1 of representative point Q1. In addition, the representative point vicinity neighboring color projection axis calculating section 41b determines, by calculation, color projection axis  $P_{j2}$  in which the contrast is maximum of edge included within the vicinity (neighbouring) region A2 of the representative point Q2.

The color projection axis synthesis section 42 synthesizes vicinity (neighbouring) optimum color projection axis  $P_{j1}$ , vicinity (neighbouring) optimum color projection axis  $P_{j2}$  respectively independently determined within the vicinity (neighbouring) regions of representative points Q1, Q2 to determine one color projection axis  $P_{j0}$  where the contrast is maximum of edge of updating section. As the

synthesis method in this case, e.g., average vector of color projection axes may be axis after synthesis.

In addition, the maximum color projection axis calculating section 32 may determine optimum color projection axis by the method shown in FIG. 37.

As shown in FIG. 37A, it is assumed that anchor point Ap0 and adjacent anchor point Ap1 are placed on edge e of picture image. At this time, since there is the possibility that the edge e may deviate to much degree from the line segment connecting Ap0 and Ap1, there is carried out search of region where color change is the greatest within the range of length H on the line segment in a direction perpendicular to Ap0Ap1 with respect to three points placed every equal interval with respect to line segment length L on the line segment Ap0Ap1, e.g., interval of L/4.

When color with respect to a certain point r is assumed to be  $C(r)$ , it is defined that color change vector is  $dC/dr$  and its magnitude is  $|dC/dr|$ . Thus, r in which this value takes the maximum value is determined.

As the result of search,  $r0, r1, r2$  are assumed to be determined as shown in FIG. 37B. At this time, color change vectors  $dC/dr$  are respectively determined at  $r0, r1, r2$  to allow its average value to be optimum color projection axis.

In addition, color change vector may be determined in a manner described below. In the case of  $r0$ , colors  $C(s00), C(s01)$  are determined with respect to points  $s00, s01$  having  $r0$  as center and away from each other by distance width  $h$  on the straight line perpendicular to the line segment  $Ap0Ap1$ . Thus, color change vector is

substituted for its difference vector  $\Delta C = C(s01) - C(s00)$ . In connection with  $r1$ ,  $r2$ , color change vectors are respectively similarly determined.

Ordinary contour closed curve generating unit generates contour closed curve on the basis of the optimum color projection axis which has been explained. At the step S105, intermediate shape based on this contour closed curve is prepared.

In addition, when algorithm shown in FIG. 19 is deformed and linear interpolation at the step S102 fails to be carried out because, e.g., movement of picture image is suddenly carried out, the processing of the step S105 may be carried out.

As described above, in accordance with this invention, positional shift between shape by linear interpolation and shape actually determined, which was problem of the prior art, can be solved.

#### Industrial Applicability

As previously mentioned, in accordance with this invention, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour. Thus, contour shape having higher precision can be prepared.

## CLAIMS

1. A curve generating apparatus adapted for generating, from curve to be generated or processed of first frame, curve at second frame,  
the apparatus comprising:  
correspondence point detecting means for determining, by using the curve to be generated of the first frame, correspondence point at the second frame corresponding to reference correspondence point set on the curve to be generated of the first frame;  
and  
curve generating means for generating curve of the second frame passing through the correspondence point detected by the correspondence point detecting means.
2. The curve generating apparatus as set forth in claim 1,  
wherein the correspondence point detecting means carries out picture image pursuit of reference correspondence point set on the curve to be generated of the first frame to determine correspondence point at the second frame.
3. The curve generating apparatus as set forth in claim 1,  
wherein the curve generating means is adapted so that when the first frame is caused to be frame at the time of start and frame at the time of end is caused to be third frame, it determines interpolated curve by linear interpolation from curve to be

generated of the first frame and curve of the third frame to deform this interpolated curve into curve passing through the correspondence point detected by the correspondence point detecting means.

4. The curve generating apparatus as set forth in claim 1,  
wherein the curve generating means generates, as curve, shape along edge  
of picture image passing through correspondence point detected by the  
correspondence point detecting means.
  
5. The curve generating apparatus as set forth in claim 1,  
wherein the curve generating means generates contour curve of object on  
picture image.
  
6. A curve generating method for generating, from curve to be generated or  
processed of first  
frame, curve at second frame,  
the method comprising:  
a correspondence point detection step of determining, by using curve to be  
generated of the first frame, correspondence point at the second frame corresponding  
to reference correspondence point set on the curve to be generated of the first frame;  
and

a curve generating step of generating curve of the second frame passing through the correspondence point detected by the correspondence point detection step.

7. The curve generating method as set forth in claim 6,

wherein, at the correspondence point detection step, a procedure is taken to carry out picture image pursuit of reference correspondence point set on the curve to be generated of the first frame to determine correspondence point at the second frame.

8. The curve generating method as set forth in claim 6,

wherein, at the curve generating step, a procedure is taken such that when the first frame is assumed to be frame at the time of start and frame at the time of end is assumed to be third frame, interpolated curve is determined by linear interpolation from the curve to be generated of the first frame and curve of the third frame to deform this interpolated curve into curve passing through the correspondence point detected at the correspondence detection step.

9. The curve generating method as set forth in claim 6,

wherein, at the curve generating step, a procedure is taken to generate, as curve, shape along edge of picture image passing through correspondence point detected at the correspondence point detection step.

10. The curve generating method as set forth in claim 6,  
wherein, at the curve generating step, a procedure is taken to generate contour  
curve of object on picture image.

11. A program recording medium adapted so that there is recorded program  
relating

to curve generating processing for generating curve at second frame from curve to be  
generated or processed of first frame,

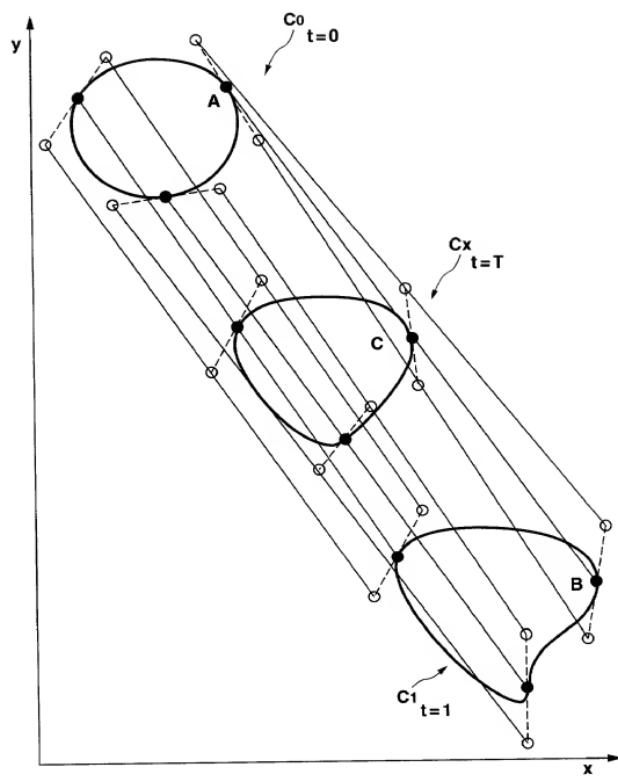
the program comprising:

a correspondence point detection step of determining, by using curve to be  
generated of the first frame, correspondence point at the second frame corresponding  
to reference correspondence point set on the curve to be generated of the first frame;  
and

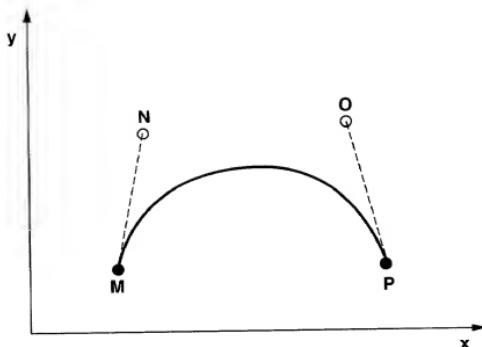
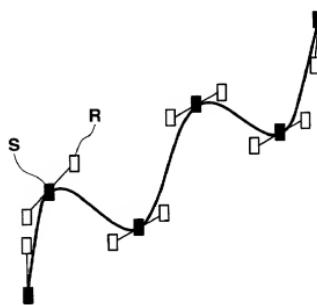
a curve generation step of generating curve of the second frame passing through  
the correspondence point detected by the correspondence detection step.

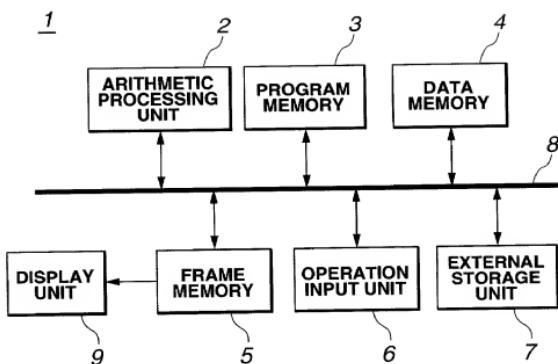
## ABSTRACT

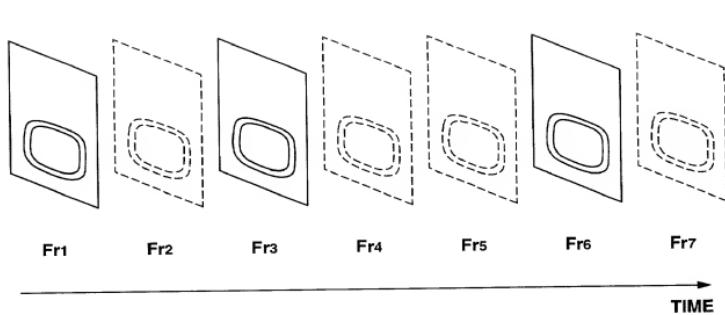
At step S101, user gives, as input, two curves at the time of start and at the time of end and reference correspondence points with respect to the respective curves. Then, at step S102, pursuit operation of reference correspondence point is carried out with respect to picture images successive in the time axis direction. As a result, positions of reference correspondence points at respective intermediate stages can be determined. Then, at step S103, interpolation of shape is carried out. Then, at step S104, interpolated shape determined at the step S103 is deformed in correspondence with reference correspondence point determined by the pursuit operation at the step S102. Accordingly, even in the case where contour shape does not linearly move, it is possible to precisely pursue correspondence points on the contour. Thus, contour shape with higher precision can be prepared.

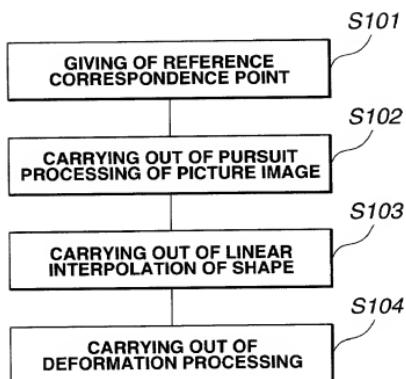
**FIG.1**

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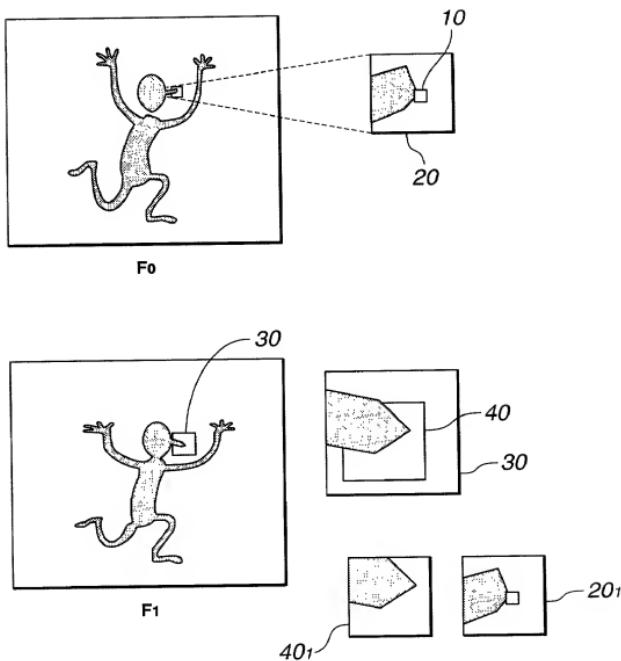
**FIG.2****FIG.3**

**FIG.4**

**FIG.5**

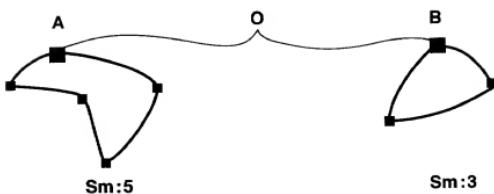


**FIG.6**

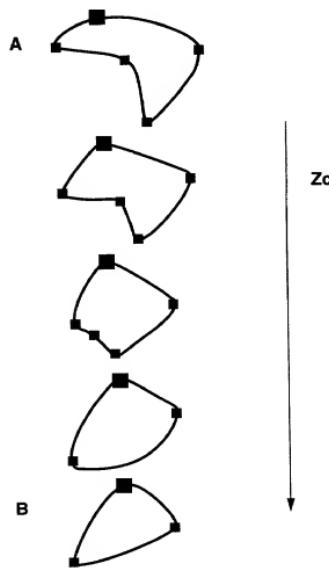
**FIG.7**

09/673202

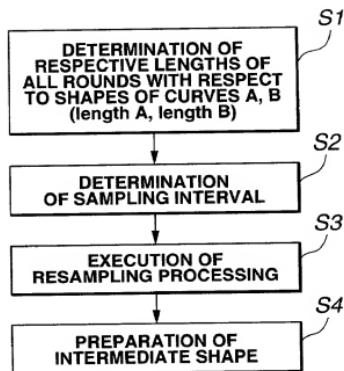
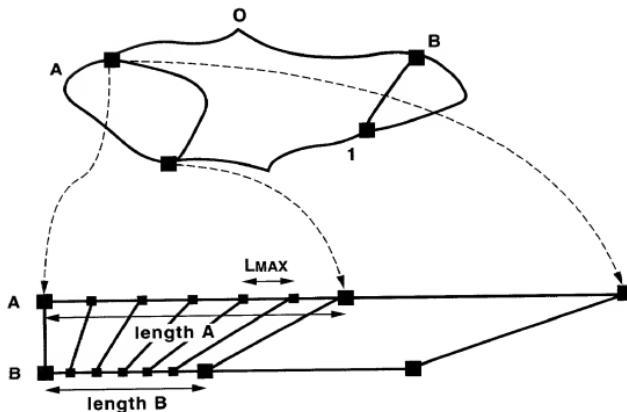
7/31

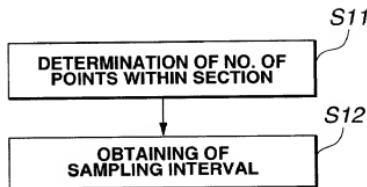


**FIG.8**

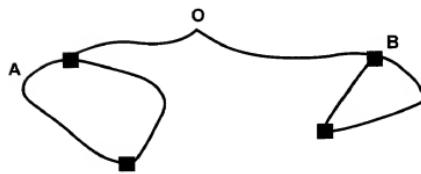


**FIG.9**

**FIG.10****FIG.11**



**FIG.12**



**FIG.13**

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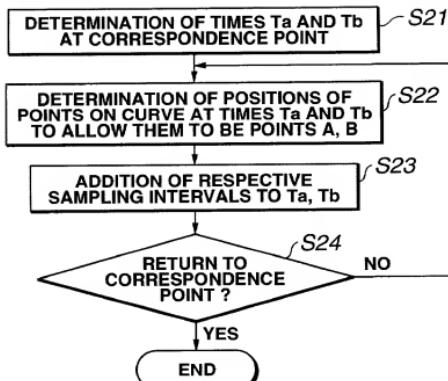


FIG.14

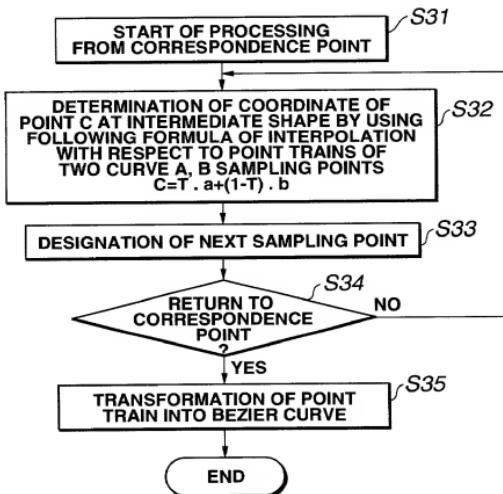


FIG.15

11/31

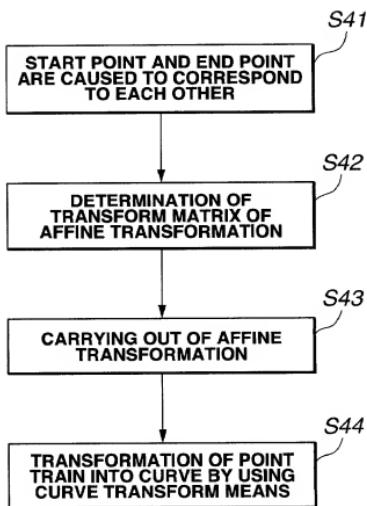


FIG.16

12/31

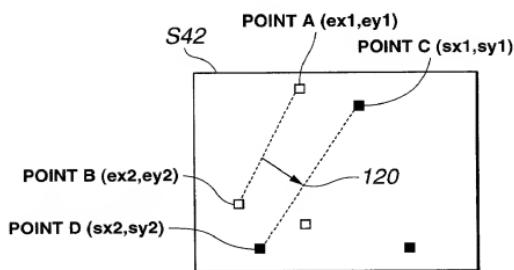
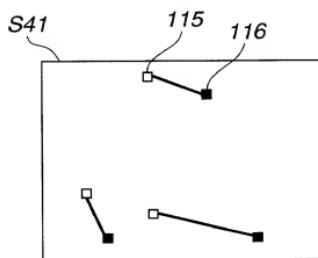
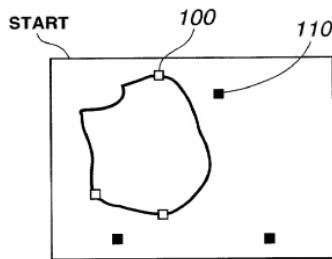
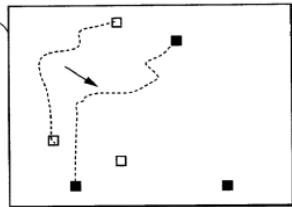


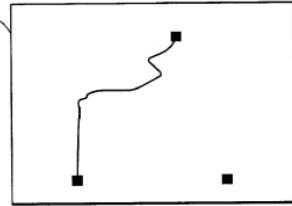
FIG.17

13/31

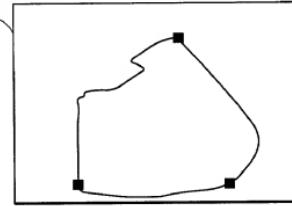
S43

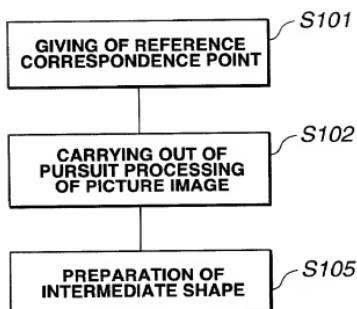


S44



END

**FIG.18**



**FIG.19**

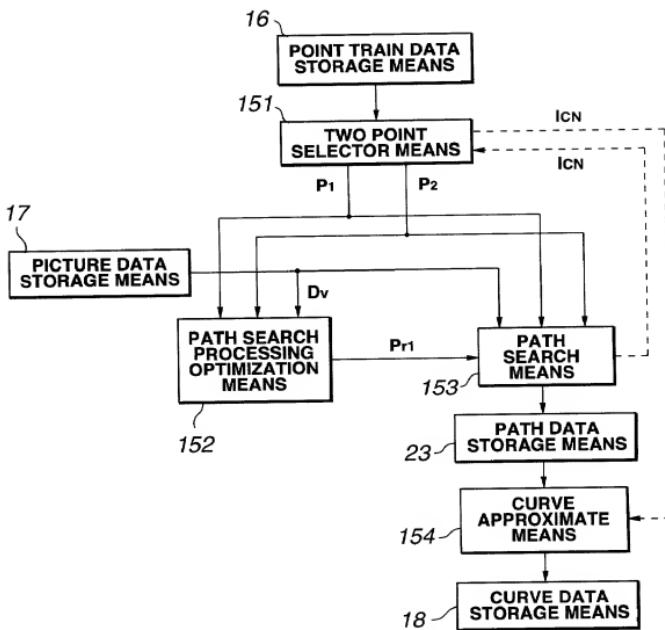


FIG.20

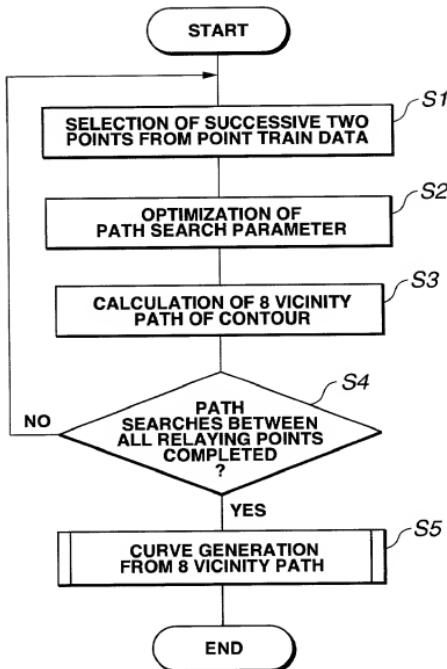


FIG.21

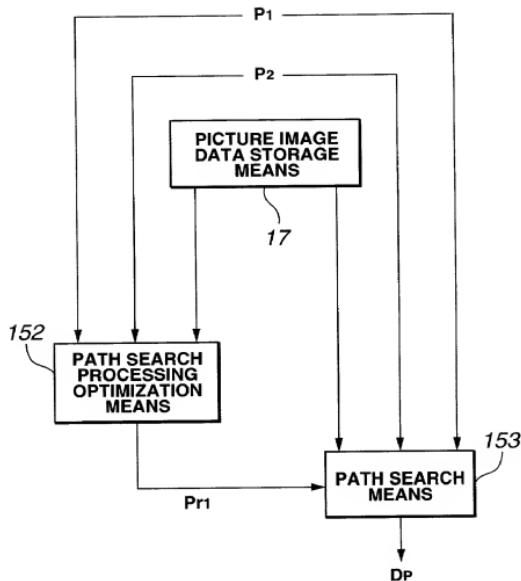


FIG.22

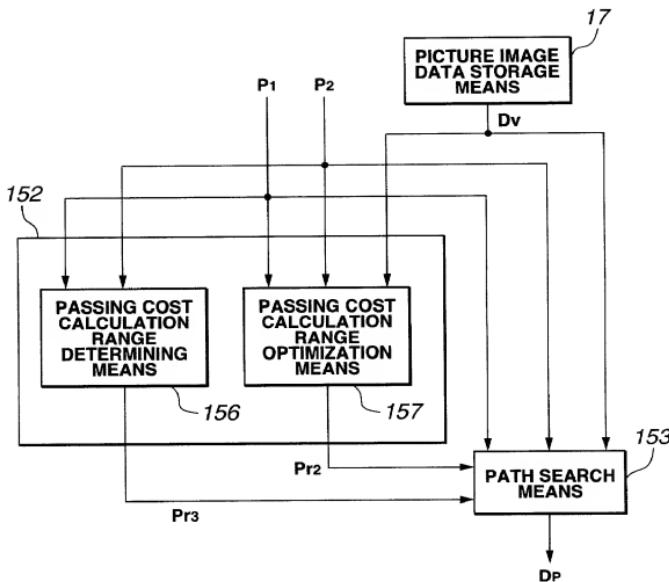
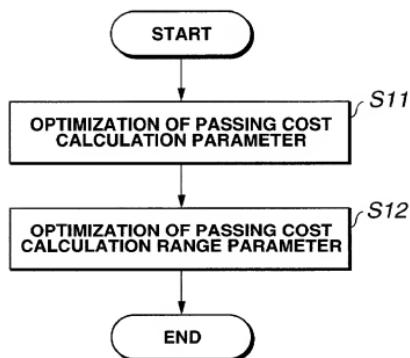
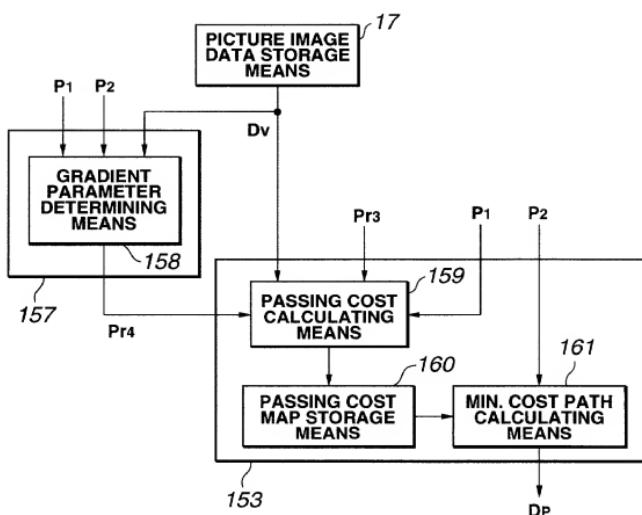
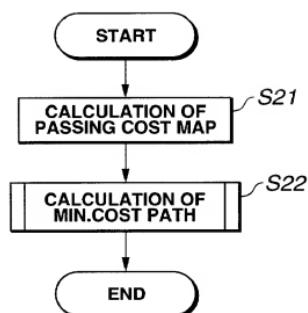


FIG.23



**FIG.24**





**FIG.26**

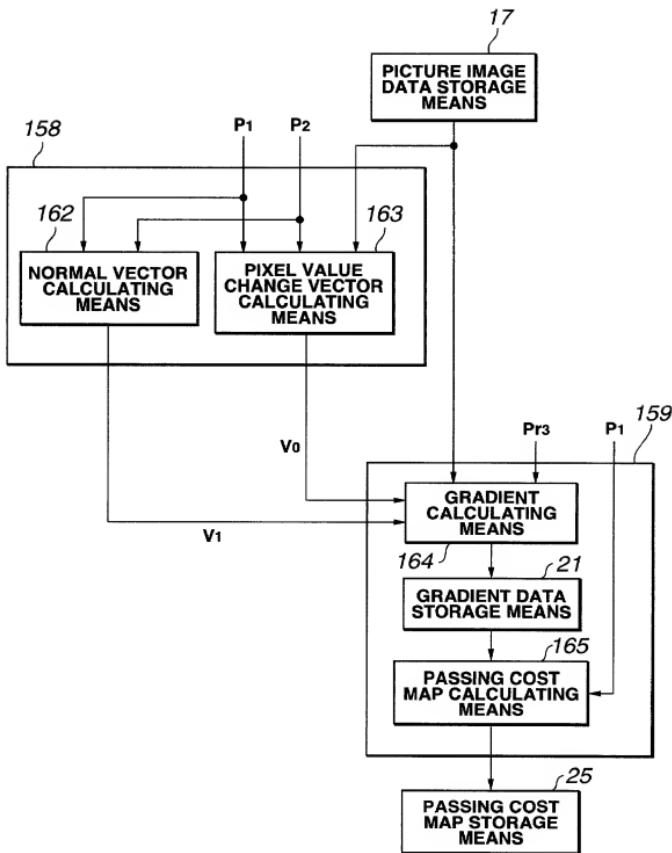
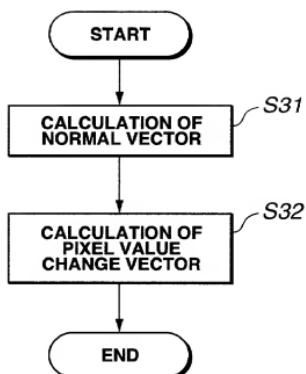
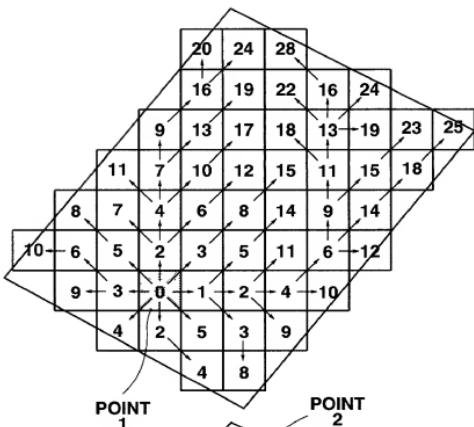


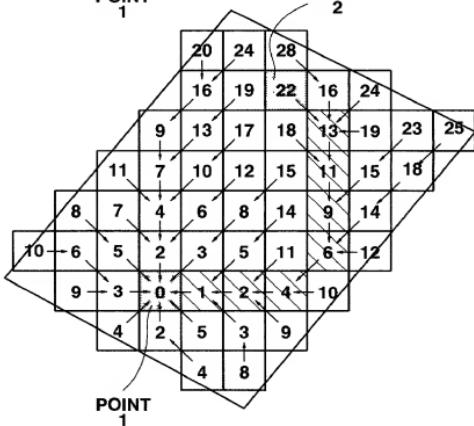
FIG.27

**FIG.28**

**FIG.29A**



**FIG.29B**



The Live-Wire 2-D dynamic programming (DP) graph search algorithm is as follows:

**Algorithm: Live-Wire 2-D DP graph search.**

**Input:**

$s$  {Start(or seed) pixel.}  
 $l(q,r)$  {Local cost function for link between pixels  $q$  and  $r$ .}

**Data Structures:**

$L$  {List of active pixels sorted by total cost (initially empty).}  
 $N(q)$  {Neighborhood set of  $q$  (contains 8 neighbors of pixel).}  
 $e(q)$  {Boolean function indicating if  $q$  has been expanded/processed.}  
 $g(q)$  {Total cost function from seed point to  $q$ .}

**Output:**

$p$  {Pointers from each pixel indicating the minimum cost path.}

**Algorithm:**

```

g(s)=0; L=s;                                {Initialize active list with zero cost seed pixel.}
while L!=NULL do begin                      {While still points to expand:}
  q=min(L);                                 {Remove minimum cost pixel  $q$  from active list.}
  e(q)=TRUE;                                {Mark  $q$  as expanded(i.e.,processed.).}
  for each  $r \in N(q)$  such that not  $e(r)$  do begin
    gtmp=g(q)+l(q,r);                      {Compute total cost to neighbor.}
    if  $r \in L$  and  $gtmp < g(r)$  then          {Remove higher cost neighbor's}
      r=L;                                  {from list}
    if !( $r \in L$ ) then begin
      g(r)=gtmp;                            {assign neighbor's total cost,}
      p(r)=q;                               {set (or reset) back pointer,}
      L=r;                                  {and place on (or return to)}
      end                                   {active list.}
    end
  end
end

```

**FIG.30**

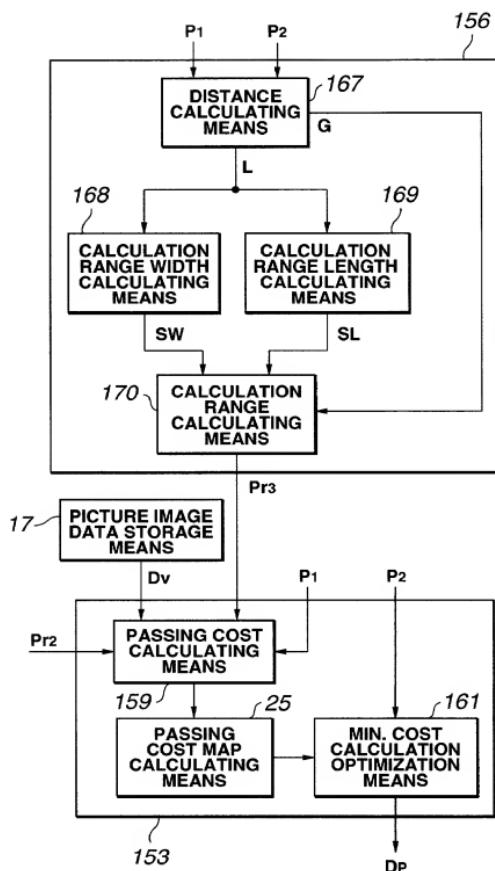


FIG.31

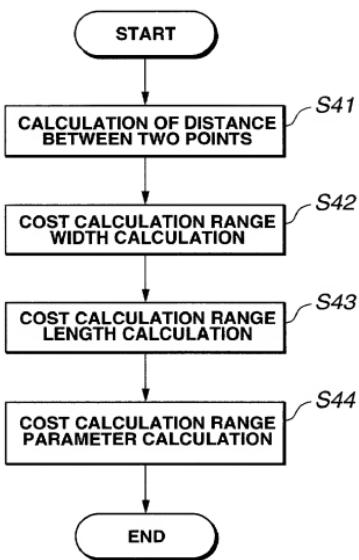


FIG.32

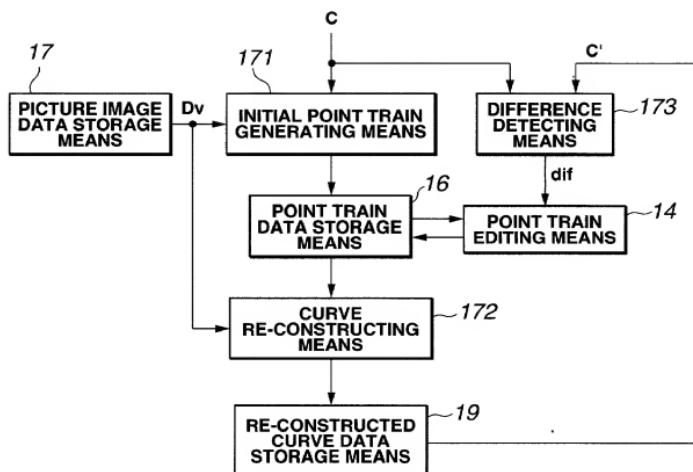


FIG.33

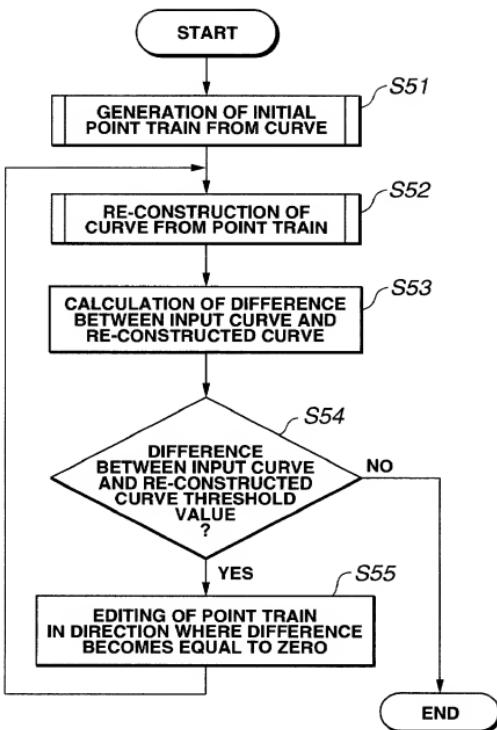


FIG.34

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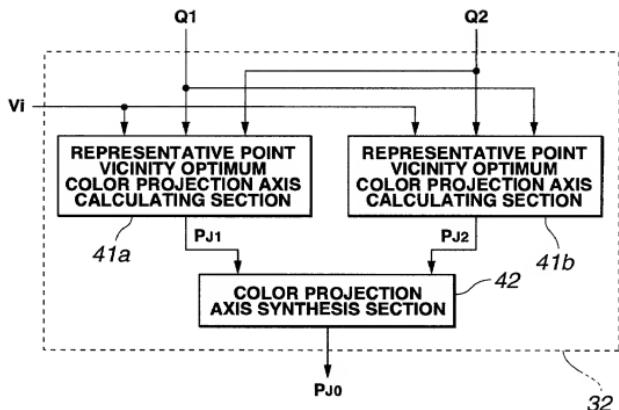


FIG.35

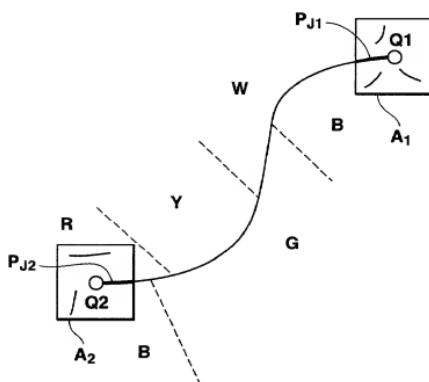


FIG.36

FIG.37B

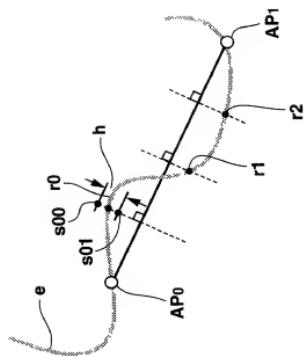
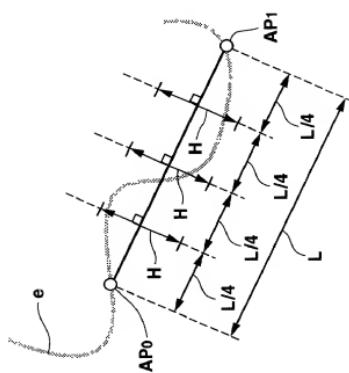


FIG.37A



091673202

Atty Docket No. K01K-T0215

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

## CURVE GENERATING APPARATUS AND CURVE GENERATING METHOD, AND PROGRAM RECORDING MEDIUM

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
			<u>Yes</u>	<u>No</u>
P11-051867 Number	Japan Country	26 February 1999 Day/Month/Year Filed	<input checked="" type="checkbox"/>	<input type="checkbox"/>
PCT/JP00/01123 Number	PCT Country	25 February 2000 Day/Month/Year Filed	<input checked="" type="checkbox"/>	<input type="checkbox"/>

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) below.

Application Number Filing Date

---

Application Number Filing Date

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I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose all information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application Number: 123456789 | Filing Date: 2023-01-01 | Status: Patented, Pending, Abandoned

Application Number: Filing Date: Status: Patented Pending Application

I HEREBY APPOINT THE FOLLOWING AS MY ATTORNEYS WITH FULL POWER OF SUBSTITUTION TO PROSECUTE  
THIS APPLICATION AND TRANSLATE ALL BUSINESS IN THE PATENT OFFICE CONNECTED THEREWITH:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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